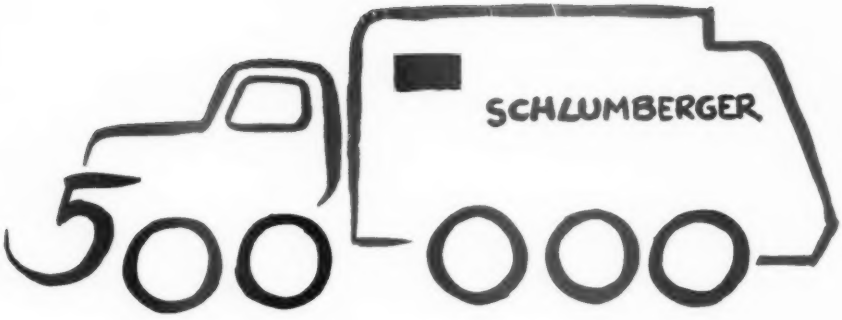
JOURNAL OF

Petroleum Technology

APRIL, 1952



500 000 OPERATIONS IN THE USA

NO SUBSTITUTE FOR EXPERIENCE!

WHY OPERATORS PREFER SCHLUMBERGER!

GEARED TO GREATER GOALS!

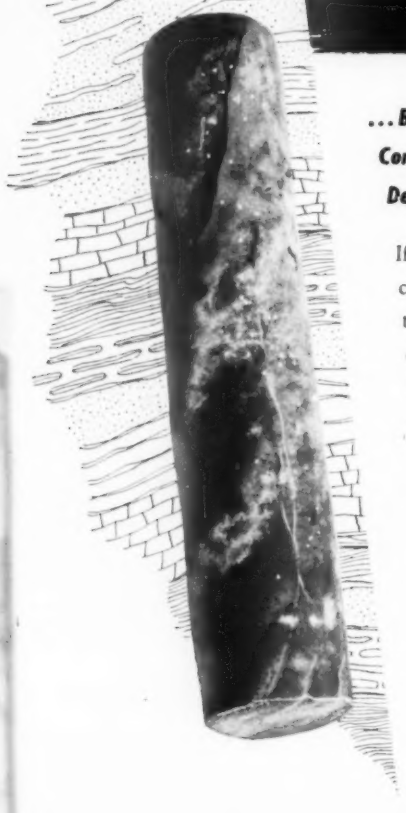
The big manufacturing plant at Halliburton's headquarters is geared to reach the new goals set by increased oil production. Master craftsmen are teamed with modern machinery to manufacture the major portion of equipment, tools, and supplies used in Halliburton's services.

Their unswerving pride of craftsmanship, supported by 25 years' energetic research and million-well experience, is your assurance that Halliburton's equipment will continue to be especially accurate, dependable, and efficient as deeper wells are drilled and greater temperatures and pressures are encountered.

"THERE'S NO SUBSTITUTE FOR EXPERIENCE IN OIL WELL CEMENTING"

HALLIBURTON
OIL WELL CEMENTING CO.
DUNCAN, OKLAHOMA

NOT JUST A MUDCAKE SAMPLE



...But A Natural, Un-compressed, Un-contaminated Core of Formation—Hard Dense Lime—Cut From A Specified Depth With An A-1 Rotary-Type Side Wall Core Barrel

If you want, and expect to get a complete and proper core analysis, you must have a natural core of the formation to start with. Such cores can be taken only by cutting out the formation as you drill, or by taking it from the side wall of open hole with a core cutting tool. Cores of formation in its natural state in the ground, can be taken *uncompressed by explosive forces, uncontaminated by wall mudcake,* and (by testimony of core analysis laboratories) *in more than sufficient amount for every analytical test* with the A-1 Rotary-Type Side Wall Core Barrel.

A-1 engineers, knowing that mud is often caked greater than one inch thick on the side wall, have designed a tool which reaches deep into the formation. In past operation the A-1 Rotary-Type Side Wall Core Barrel has taken cores which average 5.8" in length with a diameter of 1¼".

A-1 BIT & TOOL COMPANY

2000 HUSSION STREET • BOX 2133 • CHarter 7611 • HOUSTON

DISTRICT OFFICES AND SERVICE POINTS:

TEXAS
Beaumont
Corpus Christi
Kilgore
Midland
Victoria

CALIFORNIA
Los Angeles
Baash-Ross Tool Co.

LOUISIANA
Houma
Lafayette
Lake Charles
New Orleans

MISSISSIPPI
Brookhaven

OKLAHOMA
Duncan
Oklahoma City

WYOMING
Casper
W. A. Posey
(Sure-Shot)
Baash-Ross Tool Co.
(Sidewall Cores, Milling, Side-Tracking, and Burris Key Seat Wiper)

ILLINOIS
Olney
Baash-Ross Tool Co.

CANADA
Calgary and Edmondton
Imsort Tool Co.

EXPORT REPRESENTATIVES:

SOUTH AMERICA:
C. R. Summers,
Avila Hotel,
Caracas,
Venezuela

NEW YORK, N. Y.
Beckley, Haltom & Hickman
30 Rockefeller Plaza

ARGENTINA:
Langley y Cia.
Corrientes 1115
Buenos Aires

NEAR & FAR EAST
W. O. Calvert
20 Copthall Ave.
London E. C. 2
England

MEXICO
J. E. Douglas
2nd Natl. Bank Bldg.
Houston, Texas

MAIL COUPON NOW

A-1 BIT & TOOL CO., P. O. BOX 2133, HOUSTON, TEXAS

Gentlemen: Please send me your latest operation data on the A-1 Side Wall Core Barrel.

Name_____

Address_____

City_____ State_____

JOURNAL OF
Petroleum Technology

EDITORIAL BOARD

PAUL R. TURNBULL
RICHARD W. FRENCH
THOMAS C. FRICK

EDITORIAL DIRECTOR

JOE B. ALFORD

EDITOR

JESS E. ADKINS

ASSOCIATE EDITOR

VIRGINIA BEILHARZ

EDITORIAL ASSISTANTS

BEKY YODER
GLADYS PULLY

JOURNAL OF PETROLEUM TECHNOLOGY is published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., at 29 W. 39th St., New York 18, N. Y. Entered as second class matter January 31, 1949, at the Post Office at New York, N. Y., under the Act of March 3, 1879. Additional entry at Dallas, Texas. Domestic Subscription: North, South and Central America, $8; foreign, $9; to AIME members, $6 (or $4 if in combination with subscription to either Journal of Metals or Mining Engineering). Single copies, 75 cents; special issues, $1.50. Registered cable address, AIME. Printed in USA. Copyright 1952 by American Institute of Mining & Metallurgical Engineers.

Official Publication of the
PETROLEUM BRANCH
American Institute of Mining and Metallurgical Engineers
408 Trinity Universal Building
Dallas, Texas

Statements and opinions contained in the JOURNAL OF PETROLEUM TECHNOLOGY are, unless otherwise indicated, attributable only to the author, and do not necessarily reflect the views of the AIME, its officers, committees, or other agencies.

ADVERTISING REPRESENTATIVES

Chicago — William R. Stewart, 9 S. Clinton Street.
Dallas — McDonald-Thompson Co., 1118 Odeans Drive.
Fresno — McDonald-Thompson Co., 750 Fulton Street
Los Angeles — McDonald-Thompson Co., 3727 W. Sixth Street.
New York — Lewis V. Hohl, 205 E. 42nd Street.
San Francisco — McDonald-Thompson Co., 625 Market Street.
Seattle — McDonald-Thompson Co., Terminal Sales Building.

OFFICERS of the PETROLEUM BRANCH

Chairman
Paul R. Turnbull
La Gloria Corp.
Corpus Christi, Texas

Vice-Chairmen

Morris Muskat
Gulf Oil Corp.
Pittsburgh, Pa.

John R. McMillan
Fullerton Oil Co.
Pasadena, Calif.

EXECUTIVE COMMITTEE

John S. Bell
Humble Oil & Refining Co.
Los Angeles, Calif.

Thomas C. Frick
Atlantic Refining Co.
Midland, Texas

D. V. Carter
Magnolia Petroleum Co.
Dallas, Texas

E. N. Van Duzee
Shell Oil Co.
New Orleans, La.

R. C. Earlougher
Earlougher Engineering
Tulsa, Okla.

G. L. Yates
Amstutz & Yates
Wichita, Kansas

Richard W. French
Sohio Petroleum Co.
Cleveland, Ohio

Charles R. Dodson
University of Southern California
Los Angeles, Calif.
Representing M.I.E.D.

Louis C. Raymond
Ford, Bacon & Davis, Inc.
New York, N. Y.
Representing M.E.D.

Treasurer
W. E. Stiles
Buffalo Oil Co.
Dallas, Texas

Executive Secretary
Joe B. Alford
AIME
Dallas, Texas

Counsel
Robert E. Hardwicke
Hardwicke & Hardwicke
Fort Worth, Texas

COMMITTEE CHAIRMEN and VICE-CHAIRMEN

Publications
John P. Hammond
Amerada Petroleum Corp.
Tulsa, Okla.

Membership
Jack M. Moore
Dowell Incorporated
Midland, Texas

Economics
Kenneth E. Hill
Chase National Bank
New York, N. Y.

Production Review
E. H. Berlin, Chairman
Standard-Vacuum Co.
New York, N. Y.

R. B. Gilmore, Domestic
DeGolyer & MacNaughton
Dallas, Texas

A. H. Chapman, Foreign
Arabian American Oil Co.
New York, N. Y.

Advertising
Bruce Barkis
B & W, Inc.
Houston, Texas

Technology
Douglas Ragland, Chairman
Humble Oil & Refining Co.
Houston, Texas

Jack H. Abernathy, Drilling
Big Chief Drilling Co.
Oklahoma City, Okla.

E. P. Hayes, Production
The Texas Co.
Houston, Texas

W. H. Justice, Gas
La Gloria Corp.
Corpus Christi, Texas

Milton E. Loy, California
Schlumberger Well Surveying Corp.
Los Angeles, Calif.

Education
John C. Calhoun, Jr.
Pennsylvania State College
State College, Pa.

Student Activities
W. S. Morris
East Texas Salt Water Disposal Co.
Kilgore, Texas

OFFICERS OF THE AIME

President, Michael L. Haider; Vice-Presidents, R. W. Thomas, J. L. Gillson, O. B. J. Fraser and James B. Morrow; President-Elect and Treasurer, Andrew Fletcher; Secretary, E. H. Robie.

Moore

Economical Operations for....

SHALLOW WELL DRILLING
DEEP WELL SERVICING

Two trucks are all you need to transport the Lee C. Moore 87′ and the 96′ Cantilever-Type Masts. All assembling is done on the ground, and in minutes the mast can be raised to drilling position. Because of the 87′ and 96′ masts' ease of transportation, speed of erection and rugged construction, you can always be sure of economical shallow well drilling or deep well servicing.

Lee C. Moore 87′ and 96′ Cantilever-Type Masts are fabricated in four welded sections, and skid base. Can be used with standard rotary table and other equipment. Has a nominal capacity of 300,000 lbs. Furnished complete with Crown block and racking platform.

WRITE FOR BULLETIN

LEE C. MOORE CORPORATION

TULSA • DALLAS • HOUSTON • MIDLAND • SHREVEPORT • WICHITA • CENTRALIA • PITTSBURGH

Export Office — 9 Rockefeller Plaza, New York 20, N. Y.

THE PROFESSIONAL MAGAZINE FOR PETROLEUM ENGINEERS

Journal of Petroleum Technology

Vol. IV APRIL, 1952 No. 4

TABLE OF CONTENTS

Editorial Features — Section 1

Foreign Production and Development During 1951 . . 11
Weather and Oceanographic Problems in the Petroleum Industry, by A. H. Glenn 19
Tools and Techniques for Directional Drilling, reported by J. A. Klotz 23
Observations on Permeability Profiles, reported by W. F. West 27
Petroleum Branch Fall Meetings, 1952 28

Petroleum Transactions

A Simplified Method for Computing Oil Recoveries by Gas or Water Drive, by Henry J. Welge 91
Equilibrium Vaporization Ratios for Nitrogen, Methane, Carbon Dioxide, Ethane and Hydrogen Sulfide in Absorber Oil—Natural Gas and Crude Oil—Natural Gas Systems, by R. H. Jacoby and M. J. Rzasa . . 99
Correlation of Radioactive Logs of the Lansing and Kansas City Groups in Central Kansas, by John V. Morgan . 111

Institute Affairs — Section 2

Drift of Things, by Edward H. Robie 1
Petroleum Branch Affairs, by Joe B. Alford 1
Personals 3
Employment Notices 4
Petroleum Branch Membership 4
Income and Expense Statement for 1951 6
Book Reviews 10
Advertisers' Index 10

On the Cover — The weather sometimes plays a deadly game with men drilling for and producing oil from beneath the continental shelf. Here, on this month's cover, is a remarkable picture showing two waterspouts (seagoing twisters) breaking over and around an offshore drilling platform in the Gulf of Mexico. Although these phenomena are not frequent, they are potentially destructive. *Photo courtesy Humble Oil and Refining Co.*

B and W SCRATCHERS AND CENTRALIZERS FOR A Good CEMENT JOB

B and W LATCH-ON CENTRALIZER

With the NEW KON-KAVE BOW, Drop forged from the finest alloy spring steel.

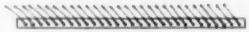
B and W MULTI-FLEX SCRATCHER

Scratches on the upstroke after casing reaches bottom.

B and W HINGED NU-COIL SCRATCHER

The coil spring, reversible scratcher. Economical and easiest to install.

B and W ROTATING SCRATCHER

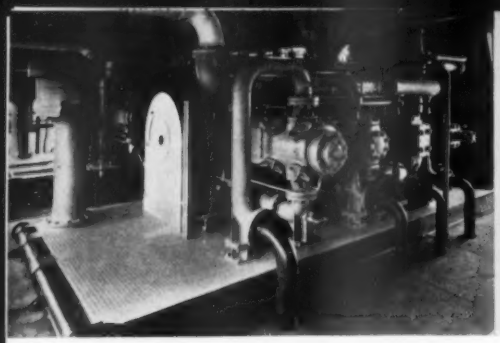


Cover the critical section — rotate until the cement is placed.

B and W Incorporated

• Well Completion Specialists •

WEST COAST — 3545 Cedar Avenue
Long Beach 7, California, Long Beach 4-8366
GULF COAST — P. O. Box 5266
Houston 12, Texas, Phone WEntworth 6603



Two Clark Midget Angles furnishing gas for gas lift service and to recycling plant at Cranfield, Miss.

Battery Two, Lake St. John Field, La.: Clark Midget Angle supplying gas to the Lake St. John gasoline and recycling plant.

Perfect Balance and

...explain Clark Midget Angles' success in The California Co.'s Bayou Country operations

Bayou country, rich in oil and gas but difficult for men and machines to work. That is the story of producing operations in the southern part of Louisiana and Mississippi. The California Company, however, has found the practical answer to the flare gas and gas lift problem in these rich producing fields.

Seventeen Clark 300 bhp Midget Angle "skid-mounted" compressor stations are now operating under extremely rugged conditions. Because of perfect balance, only a slab of concrete is needed for a foundation. Several of these skid-mounted units are even operating on small 18-foot x 36-foot, floating steel barges. Most of these field compressor stations are operated in isolated locations, with only a minimum of service and attention. It is readily apparent why a compressor selected for this toughest kind of service must be inherently rugged and durable. Only the Clark Midget Angle matches these service requirements perfectly. An on-stream average of 97 per cent of the time is proof of dependable performance.

If you have a problem involving 80 to 330 bhp gas-engine-driven compressors, for hard field service, investigate the Clark HMA for the most practical answer.

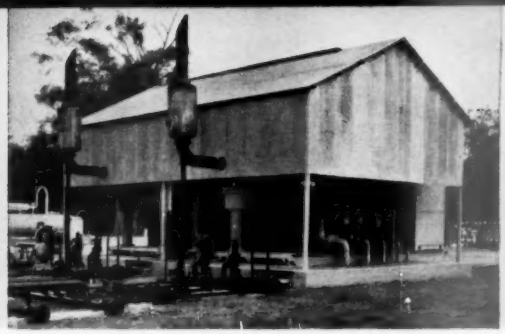
CLARK BROS. CO., INC. • OLEAN, N. Y.

One of the Dresser Industries

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

Barataria, La.: Clark Midget Angle pumping flare gas into a natural gas pipeline.

Brookhaven, Miss.: Clark Midget Angle discharging at 2500 psi into injection wells shown in background.

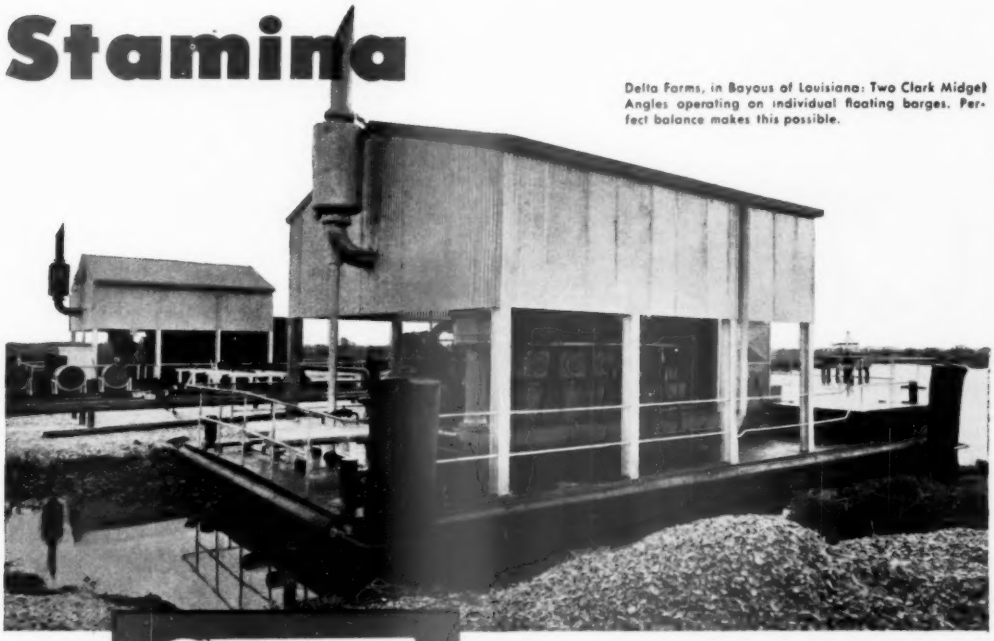


Battery Four in Lake St. John Field, La.: Two Clark Midget Angles furnishing gas for gas lift services and for gasoline plant at nearby Lake St. John.

Clark Midget Angle handling 2-pressure services of field gas for Cranfield, Miss. recycling plant.

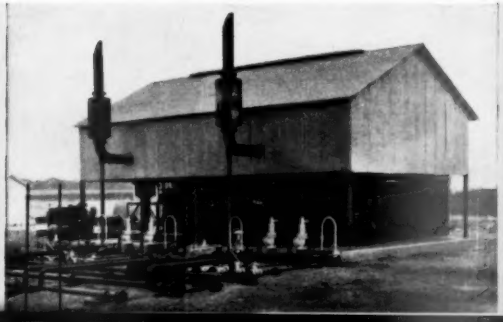
Stamina

Delta Farms, in Bayous of Louisiana: Two Clark Midget Angles operating on individual floating barges. Perfect balance makes this possible.

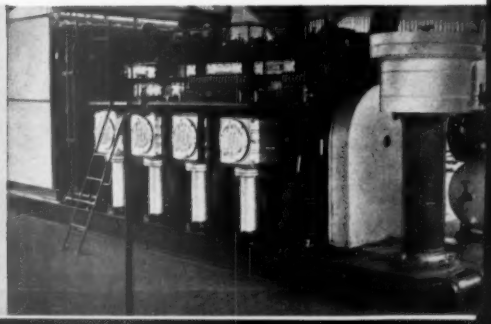


CLARK® compressors

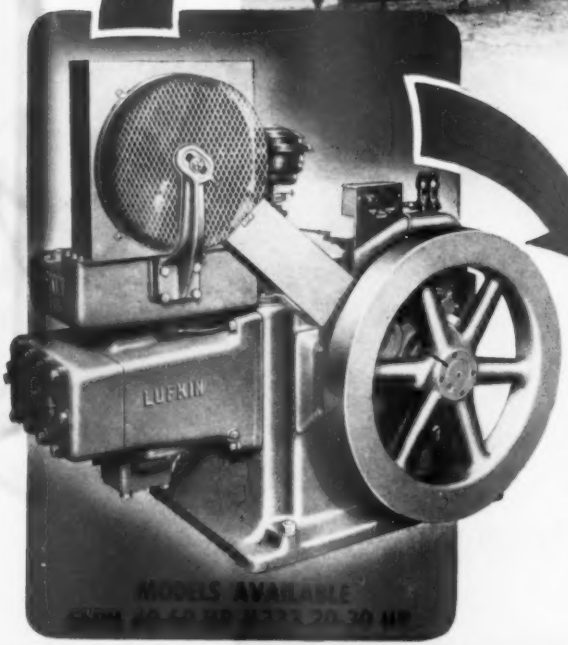
Two Clark Midget Angles supplying gas through 2-pressure services to nearby Lake St. John recycling plant.



Hico Knowles, La.: Clark Midget Angle supplying gas through 2-pressure service for nearby recycling plant.



Lufkin ENGINES



THE *Lufkin* H333

A DEPENDABLE RUGGED 20-30 HP OIL FIELD ENGINE

Lufkin engine-unit combination means one responsibility—one source for your entire surface pumping equipment. Fifty years of know-how in manufacturing oil field equipment is your assurance of satisfactory, long-life, low upkeep, and dependable service. The Lufkin H-333 gas engine is built around the needs of the oil fields.

- Two cylinder, two cycle, crosshead design for smoothness and long life.
- Condenser cooling for more efficient cooling and lubrication. High even temperatures desired for sour gases are maintained. No water pump troubles.
- Full pressure lubrication with oil under pressure forced to all wear points for longer life and trouble-free service.
- Easy starting by hand. Optional: Built in 12-volt electric starting system, or air-gas motor starting requiring only 25# gas pressure.

Lufkin engines can take it, which has been proven in the field over many years of continuous operation. We invite you to write direct or check with your nearest Lufkin representative for information and delivery.

LUFKIN FOUNDRY & MACHINE COMPANY

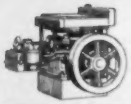
LUFKIN, TEXAS

Branch sales and service Houston, Dallas, New York, Tulsa, Los Angeles, Seminole, Oklahoma City, Corpus Christi, Odessa, Kilgore, Wichita Falls, Casper, Wyoming; Great Bend, Kansas.

Lufkin Equipment in CANADA is handled by

THE LUFKIN MACHINE CO., LTD. 14321 108th Avenue, Edmonton, Alberta, Canada.

LUFKIN PUMPING UNITS



LUFKIN-COOPER-BESSEMER ENGINES

LUFKIN OIL FIELD AND INDUSTRIAL TRUCK TRAILERS

INDUSTRIAL SPEED REDUCERS AND INCREASERS

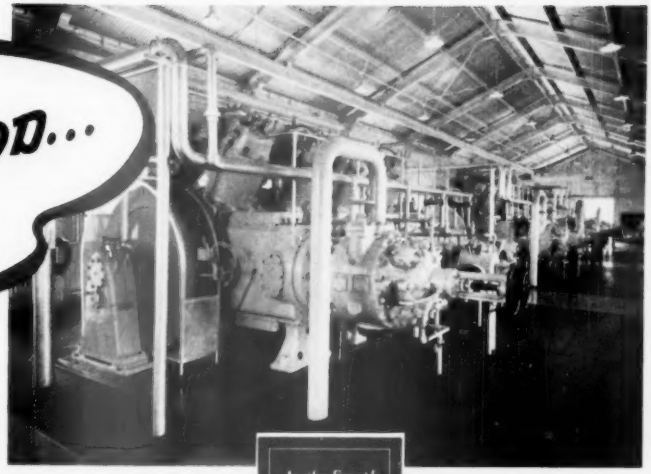
DIVISION LUFKIN FOUNDRY & MACHINE COMPANY INDUSTRIAL, MILL AND AUTOMOTIVE SUPPLIES

AT CHITWOOD...

BROAD GAS CONSERVATION

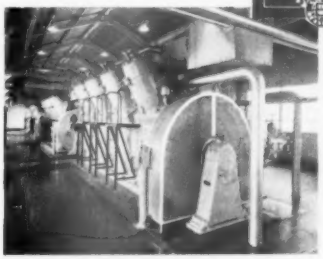
with multi-service

GMV's



Line-up of four Cooper-Bessemer 8-cylinder GMV compressors, rated 880 hp at 300 rpm, in Magnolia Petroleum Company's Chitwood Gasoline Plant. Here, multi-service operation involves 4800 psi discharge in cycling, 1,015 psi in gasoline extraction, 250 psi for vapor recovery. Flexibility is a keynote.

Another Example of Efficient Power at Lower Cost



GMV's in Magnolia Chitwood plant, shown here from crankdoor side.

Exterior view of compressor building at Magnolia's Chitwood plant.

AT THE Chitwood plant, Magnolia Petroleum Company is doing an outstanding job of gas conservation . . . perhaps unique. The operation includes production of distillate by cycling . . . production of gasoline from casinghead gas . . . vapor recovery off of crude at atmospheric pressure . . . and a pressure maintenance operation.

The operation is of particular interest because it involves both high and low pressures, together with the vapor recovery service — all tied into the same compressor units.

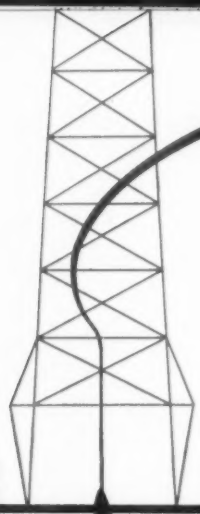
As shown opposite and below, the compressors are efficient Cooper-Bessemer GMV Turboflows — chosen partly because they assure the true flexibility so essential in a multi-service operation such as this.

Whether your plans call for complex compressor service or the most simple kind of set-up, you'll be ahead with Cooper-Bessemer V-Angles. Then you'll be *sure* of economical installation, prolonged, low-cost performance, and the *flexibility* to meet fixed or variable requirements precisely. Better check with Cooper-Bessemer.

The Cooper-Bessemer Corporation

MOUNT VERNON, OHIO — GROVE CITY, PENNA.

New York, N. Y. Washington, D. C. Bradford, Penna. Parkersburg, W. Va.
San Francisco, Calif. Houston, Dallas, Greggton, Pampa and
Odessa, Texas Seattle, Wash. Tulsa, Okla. Shreveport, La.
St. Louis, Mo. Los Angeles, Calif. Chicago, Illinois Caracas, Venezuela



something new

has been added to ***well treating***

Dowell Jel-X Services

FOR INCREASED OIL AND GAS PRODUCTION

The chemical treatment of oil and gas wells is not always just a matter of formation solubility. It is recognized that the physical state of the producing formation must also be considered. Dowell Jel-X Services are based on that consideration. They work *mechanically* as well as chemically to increase oil and gas production.

Jel-X Services are fast! Many treatments take little more than an hour; the longest treatments are usually made in less than six hours. Rig-time is held to a minimum. Most chemicals arrive at your well mixed and ready to use. What's more, shut-in time is unnecessary after treatment.

Dowell's Jel-X Services are a growing family with a variety of types to fit many different well conditions. Call the Dowell station near you for complete information.

Here's the Dowell Jel-X Family

ETCHING ACID—Jel-X 100 is a slightly viscous solution which has proved effective for use in limestone and dolomite formations with either fractured or vugular porosity. It is designed to etch and enlarge fractures or "vugs"; clean fractures by removing mud, silicate and feldspar materials; penetrate formation farther from the well bore than ordinary acid.

CHANNELING ACID—Jel-X 200 is a fairly viscous solution which has proved effective in limestone and dolomite with some intergranular porosity. It is designed to form channels deep into pay formations. These channels permit the entrance of acid into zones far from the well bore, reaching production that might otherwise be untapped.

STRATA-LIFT—Jel-X 300 and 400 are very viscous solutions which have proved effective in problem wells completed in dense limestone or dolomite. They are designed to open new fractures and extend old ones, and to dissolve soluble portions of the formation. Strata-lift may carry suspended sand which operates as a propping or abrading agent; needs no following jel-breaker solution.

STRATA-FRAC—Jel-X 500 is a fairly viscous fluid which has proved effective in sandstone, chert, chat and conglomerate formations. It is designed to dissolve soluble materials including silicates, paraffins and other heavy hydrocarbons; and to open new fractures or enlarge old ones. Strata-frac carries suspended sand as a propping or abrading agent; needs no following jel-breaker solution.

TEMPORARY PLUGGING SERVICE—Jel-X 700, 800, 810 and 900 are very viscous solutions which have proved effective in selective acidizing. They are designed to shut off the more permeable zones, permitting acid to be injected into the tighter formations. They are particularly useful in wells having multiple zone completions.

DOWELL SERVICE

Acidizing • Electric Pilot • Perfo-Jet • Plastic • Paraffin Solvents
Chemical Cleaning for Heat Exchange Equipment • Jelflake • Bulk Inhibited Acid

DOWELL INCORPORATED • TULSA 1, OKLAHOMA
A Subsidiary of The Dow Chemical Company

"First in Oilfield Acidizing . . . Since 1932"

Look to **DOWELL**

FOR OIL INDUSTRY CHEMICAL SERVICE

Foreign Production and Development During 1951

The year 1951 was a year of crisis in foreign production. Almost overnight the world was short 700,000 B/D as a Result of the Iranian shutdown. But the industry filled the gap and development continued upward throughout the year.

Canada

1951 was a big year in the development of Canadian oil with new records being set in almost every phase of exploration and development activity. Most important is the continuous expansion of the land and exploration activity, the wide geographical and geological range of the oil and gas discoveries that were made during the year, and the greatly increased production, due mainly to the arrival of western Canadian crude in the province of Ontario which supplies part of the Ontario crude demand. During the year, there was an announcement of great interest to the producers, that of the construction of an oil pipe line to the West Coast from the Edmonton area to Vancouver. Also there was considerable refinery expansion across the country. And last but not least, there was the entry of the petrochemical industry into the Canadian oil picture.

In Western Canada, total acreage holdings under lease, reservation, and option form grew to approximately 168 million acres, an increase of 39 million acres during the year, or about one-third. This increase in acreage was the result of three main land plays that developed during the year. The first was in the Williston Basin area, and it was touched off by the discovery of light crude oil in the Mississippian in January, 1951, in southwestern Manitoba. Discoveries in the northern States later in the year added emphasis to this land play and some several million additional acres were taken up in the Saskatchewan, and about two million acres in Manitoba. The second land play of significance developed in northwestern Alberta, in northeastern British Columbia, and up in the Northwest Territories. This land play resulted from two things, first the competition for land by the companies that were active in the area. That was about the only direction that the play could move since most of the land that was available in the other areas to the south and east was already taken up. Secondly, this play was spurred considerably by the discovery of oil late in the year in the Fort St. John area of northeastern British Columbia. During the last two months there was a very rapid increase in the land taken out. Approximately 10 million acres were added to the acreage in British Columbia, and about four million acres were taken out in the Northwest Territories. The third land play possibly didn't have as much effect in proportion as to acreage holdings, but should be mentioned. That is the Central Alberta area, particularly southeast from Edmonton where a number of discoveries were made. This land play was highlighted by the intense competition for acreage and the rather spectacular prices that were paid even for rank wildcat acres.

Along with the greater land holdings, naturally some increase in exploration activity could be expected. During the year the seismic crew level in the area continued to be second only to Texas on the continent. The maximum number of crews in the field reached 153, with an average of 134. Approximately 1,630 party months of geophysical activity were conducted, including seismic, gravity and magnetometer. The increase during 1951 was approximately 25 per cent over the level in 1950. There was less surface geological exploration carried out and more core drill work. Some 478 exploratory wells were drilled in Western Canada. Out of the 478 well, 68 were rated as oil discovery or extensions to proven areas, and 78 were rated as gas discoveries or extensions. Of the 78 oil discoveries, 39 were classified as new field wildcats and the discovery ratio was one in 12.

There are two observations to make regarding the significance of the results of this exploratory drilling: (1) the wide geographical range of discovery, and (2) the range of geological horizons the discoveries were made in — the Cretaceous, Jurassic, Triassic, Devonian, Mississippian and Permo-Pennsylvanian. Probably the most important discovery of oil was the Texas Wizard Lake discovery a few miles southwest of Edmonton and about eight miles south of the Leduc Field. This well was a hot well. It discovered gas in the Viking zone, oil in the lower Cretaceous, oil in the D2 of the Devonian, and then ran into over 600 ft of pay in the D3 zone of the Devonian. Pre-

---

Data presented here were gathered by members of the AIME Production Review Committee under the direction of E. W. Berlin and A. H. Chapman. Canadian figures were compiled by Don Wilson, Imperial Oil Co., Ltd.; European figures by F. E. von Estorff, Standard Vacuum; Far East figures by E. W. Berlin, Standard Vacuum; Middle East figures by J. T. Duce and A. H. Chapman, Arabian American Oil Co.; and South American figures by Earl Taylor, DeGolyer & MacNaughton, Inc.

---

liminary estimates of the reserves there are in excess of 50 million bbl. In addition to Wizard Lake in the Devonian are some other discoveries east and south of Edmonton, including New Norway, Bashaw, Clive and Caprona. Of course, they all tend to emphasize the importance of this horizon in Western Canada.

Two other discoveries were made, one at Armena and another just a few miles south and east at Camrose, both of which were in the Viking sand at a depth of around 3,200 ft. These discoveries, along with the Joseph Lake Field which was discovered a couple of years ago, certainly point out the importance of the Viking sand horizon in Western Canada.

On the development side of the picture, activity continued at about the same level as in 1950 with 754 oil wells completed. During the year, drilling activity declined to almost nil in the Redwater Field as that area was drilled out. It is the largest single reserve in Canada. It is also the first of the major discoveries made during the last few years that has been fully developed. The problems of operation in this pool received considerable attention from the operators during the year and towards the end of the year a salt water disposal association was being formed. The Leduc area continued to be quite active from the development point of view with up to 40 rigs operating during various times of the year. In addition to the Wizard Lake area which was a discovery during the year, the South Calmar area was also a discovery in the D3 zone, a separate pool with a maximum pay of over 400 ft. The McLeod area was mainly a D2 zone extension of the Leduc Field itself.

The Acheson D3 area was extended considerably during the year and saw a lot of development and activity. Other areas of active development south and east of Edmonton included the Big Valley and Statler areas and New Norway, Flint and Joseph Lake.

During the year production in Western Canada reached 47.3 million bbl or about 130 thousand B/D. It represented an increase of 70 per cent over the previous year. This increase was due to the movement of Western Canadian crude to the Ontario market. It was also due to increased demands by Prairie refineries and to the development of a small outlet at Superior, Wis.

On the reserve side of the picture, preliminary estimates of oil found by new discoveries during the year totaled approximately 150 million bbl. Extensions of proven areas and revisions of reserve estimates have added another 225 million bbl to make a total of 375 million bbl of oil added to ultimate production estimates. Subtracting production of about 50 million bbl the net addition is 325 million, and year-end reserves were in the order of 1,300,000,000 bbl or greater.

In the past five years the producing phase of the Canadian oil industry has developed to the point where it is now an important part of the economy of the country. The next few years holds considerable promise for continued expansion and for the formation of a permanent and stable oil producing industry.

Brazil

The exploration program for petroleum in Brazil continued to expand during 1951. In the Amazon region, 24 party months of seismic surveys and three party months of gravity work were completed as well as eight months of surface geological investigations. The Limoeiro No. 1 test well, begun in 1950 near the mouth of the Tocantins River in the State of Para, was completed as a dry hole at 13,213 ft. The Cururu No. 1 test was spudded near the north coast of Marajo Island at the mouth of the Amazon River and was drilling below 6,000 ft at the end of the year.

In the Maranhao Basin, south of the Amazon River, 18 party months of surface geological studies and 13 months of seismic work were completed during 1951. The first wildcat test, the Carolina No. 1, was drilled to basement at about 3,900 ft and abandoned as a dry hole.

In the northeast coastal plain area, 17 party months of seismic work were completed and one wildcat test was drilling in the State of Sergipe. In the Bahia Graben, in the State of Bahia, 12 months of seismic and 20 months of geological surveys were completed. Three wildcat tests begun in 1950 were complete as successful discovery wells in 1951. Two additional wildcats were completed in 1951. Of these, one opened a new field and the other was dry. In the Parana Basin of southern Brazil, 40 party months of geological studies were completed. Two anticlinal structures were mapped and drilling locations made. One or both of these locations will probably be drilled in 1952. Total wells completed in Brazil during 1951 may be summarized as follows: oil wells, 21; gas wells, 5; dry holes, 8.

Production of Brazilian crude oil during 1951 was the largest in Brazil's history, totaling about 700,000 bbl, most of which came from the Candeias Field. This field is just north of the Mataripe Refinery in Bahia where the Brazilian crude was refined. Pumping units were being installed in the Dom Joao Field which should be ready to go into limited production during 1952.

Gas production from Brazilian fields during 1951 amounted to 269,358,842 cu ft.

During 1951, President Getulio Vargas sent to the Brazilian legislature for study a proposal to organize a National Petroleum Co., with a capital of about $500 million, to assume responsibility for all of Brazil's petroleum industry. This company would be in part government and in part private ownership. This proposal is President Vargas' solution to Brazil's fuel problem. All signs point to further expansion of petroleum exploration in Brazil by Brazilian nationals using Brazilian capital.

Bolivia

Production in Bolivia averaged about 1,600 B/D in 1951. The country's oil comes principally from three old fields with a total cumulative production of approximately 5,805,000 bbl. The remaining proved reserves are estimated at about 22,000,000 bbl.

Early in the year the government oil agency Y.P.F.B. contracted the services of Western Geophysical Co. for assistance in developing the producing areas. Three skimming plants, all owned by the government agency, are in operation. The total capacity of these plants is about 10,500 B/D.

Chile

By the end of 1951 more than 50 wells had been drilled in Chile by the Empresa Nacional del Petroleo (ENAP), the Chilean government's petroleum organization. Production of oil or gas has been found in eight fields, all in Tierra del Fuego. North of Cerro Manantiales, the original discovery, are Espora and Angostura gas fields and Punta Delgada oil and gas field. South of Manantiales are the Victoria Norte, Victoria Sur and Sombrero oil fields and the Chanarcillo gas field. Wildcat drilling is in progress to the southwest of this producing trend in the Miraflores district.

A gasoline plant designed for treating 282,512 cu ft of gas daily, is under construction at Cerro Manantiales. The Cerro Manantiales-to-Caleta Clarencia pipeline, more than 40 miles long, was completed during 1951. Storage capacity is now 340,000 bbl in this area. A proposed $10 million refinery to be located north of Valparaiso is now in the design stage.

The contract was awarded to the M. W. Kellogg Co. by Empresa Nacional del Petroleo. Capacity of the plant will be 20,000 B/D.

Colombia

Crude production in Colombia averaged about 105,000 B/D in 1951, an increase of about 11,700 bbl over the figure for 1950. Most of the gain is due to the greatly increased production from Shell's Yondo concession. The remaining reserves of the country are now estimated at about 450,000,000 bbl.

On August 25 the 30-year term of the DeMares concession expired and on that date Tropical Oil Co. turned back to the government title to the concession together with the refinery at Barranca Bermeja and all other facilities which the company had installed during its period of tenure. The DeMares concession will now be operated by the Empresa Colombiana de Petroleos, an autonomous agency set up by the government to manage oil properties belonging to the nation.

With the reversion of the DeMares concession to the government the Tropical Oil Co. as such ceased to exist. It is replaced by two new companies. The marketing of petroleum products in Colombia will henceforth be handled by Esso Colombiana S. A. and the International Petroleum Co. of Colombia (Intercol) has been organized to take over the development of the exploratory concessions formerly held by Tropical.

According to the terms of the agreement worked out between Tropical and the government International Petroleum of Colombia (Intercol) will operate the refinery at Barranca Bermeja under a lease arrangement with Empresa Colombiana and will furnish technical assistance on a cost-plus basis for the future development of the DeMares Field.

Colombian refining capacity is about 37,000 B/D at the present time; however, plans are underway to enlarge and modernize the refinery at Barranca Bermeja. The Texas Co. has obtained a permit to build a pipeline from the Velasquez Field to the river port of La Dorada where Intercol is setting up a small topping plant.

A products line is under construction from Puerto Salgar, on the Magdalena River opposite La Dorada, to Bogota and will be extended to the refinery at Barranca Bermeja at a later date. When completed this line will eliminate difficulties that have been experienced in transporting refined products to Bogota by rail and river boats.

During the year The Texas Co. completed Ortega No. 1 for a new field opener in the Tetuan block in the upper Magdalena Valley. The well was drilled to 5,801 ft. It is about 10 miles north of the Tetuan Field and is on a separate structure. Initial production was 323 B/D, 29.2° oil on a $\frac{1}{4}$-in. choke. Probably the most significant development was the discovery of Cretaceous production in the Totumal concession about 75 miles north of DeMares. The discovery well Totumal No. 1 was drilled by Intercol to a depth of 7,217 ft with $8\frac{5}{8}$-in. casing set at 6,740 ft. On production test the well flowed 550 bbl of 25° oil in 12 hours on a $\frac{1}{2}$-in. choke. Intercol is drilling a wildcat (Rio Maracas No. 1) in the northeastern part of Colombia about 120 miles south of Riohacha. Richmond Petroleum Co. has two exploratory concessions in this part of the country and is at present drilling a wildcat on one of them about 40 miles south of Riohacha. The well, Perico No. 1, had attained a depth of 7,600 ft at the end of the year.

The number of wells drilled in 1951 was 116, a gain of 17 over the number drilled in 1950. Six wildcats were drilled during the year. Of these, three were successful and three were dry. There were 15 drilling rigs in operation in Colombia at the end of the year.

Ecuador

Ecuador's production in 1951 averaged about 7,400 B/D. The cumulative total production since development first began is approximately 53,000,000 bbl and the remaining proven reserves of the country are currently estimated at 25,000,000 bbl.

Production at the present time is confined to a strip along the coast in the western part of the country. There are two principal operating companies, the Anglo-Ecuadorean Oilfields, Ltd. and the Marabi Exploration Co. Nine rigs were active in 1951. Two skimming plants are in operation. One is owned by Anglo-Ecuadorean and the other by Marabi. Total capacity of the two plants amounts to about 7,000 B/D.

Mexico

Mexico's daily average production was approximately 210,000 bbl in 1951. The remaining reserves are estimated to be approximately 1,400,000,000 bbl. Two hundred and sixty-seven wells were drilled during the year, a gain of 44 over the number for the preceding year.

Three new oil fields were discovered in the Isthmus region. These are: Jose Colomo, Rabon Grande and Concepcion. In addition to these discoveries in the south, two new producing areas were found in Northeast Mexico. Trevino No. 101 was completed as a small well on the Trevino prospect where two previous unsuccessful wells had been drilled, and Lomitas No. 101 was completed as a gas well in the Mision area.

Improvements were made to the pressure maintenance system of the Poza Rica Field which are expected to permit a large increase in the withdrawal rate from this field. Refinery facilities are available for processing about 178,350 bbl of crude daily; however, this capacity will be increased when plans for new construction are carried out.

During the year a products line was constructed across the Isthmus of Tehuantepec to the Pacific coast port of Salina Cruz. This line will be converted to the transportation of crude when the projected refinery at Salina Cruz is built. Also during the year a 12-in. gas line was constructed from Mision to Matamoros and work is now in progress on a 16-in. gas line from Monterrey to Torreon. A 10-in. pipeline for movement of crude oil from the new Jose Colomo Field to the El Plan Field is also being constructed.

Pemex purchased the properties and facilities in Mexico of the Gulf Oil Co. and arrived at an agreement with Sinclair Oil Co. regarding the latter's holdings in Northeast Mexico. Through these deals Pemex has acquired the last of the major holdings of foreign oil companies in Mexico.

Peru

Daily production in Peru in 1951 was approximately 44,300 bbl and reserves are currently estimated at 170,000,000 bbl. A new petroleum law granting favorable terms to foreign investors has recently been approved and exploration permits have already been taken out by several foreign companies. Geophysical work is being conducted in various parts of the country. Three refineries are in operation with a total capacity of about 38,000 B/D.

Uruguay

Exploration for petroleum under the direction of the Administracion Nacional de Combustibles, Alcohol y Portland (Ancap) continued during 1951 in the basalt-covered sedimentary basin of Northwestern Uruguay. This program is principally geophysical and includes gravity, magnetic, and electrical resistivity surveys. By the end of 1951, approximately 17 party months of geophysical work had been completed. A preliminary evaluation of results indicates that usable data are being

obtained and that anomalous structures below the thick basalt cover are being mapped.

During 1952 the Ancap plans to expand the geophysical work in order that the prospective basin area may be surveyed more rapidly. It is hoped that by the end of 1952 it will be possible to select areas for detailing which will eventually provide suitable sites for test wells.

Venezuela

The rate of crude production in Venezuela continued to rise steadily in 1951. Increased drilling activity and recent new discoveries indicate that the upward trend will continue for some time to come. It is expected that the decision of the government to grant new concessions to new and old concessionaires will also add stimulus to the country's production. The daily average for 1951 was 1,698,000 bbl, an increase of 200,000 B/D over the 1950 figure. The number of active drilling rigs increased from 78 at the beginning of 1951 to 110 at the beginning of 1952.

During the year a gas distributing line was laid by the Venezuelan Atlantic Transmission Corp. from the Placer district of the State of Guarico to Caracas. This system will eventually be extended to include the cities of La Guaira, La Victoria, Maracay and Valencia. Work was also started on a crude line by Shell Oil Co. and associates from the Mara Field northwest of Maracaibo to the refineries and deep water terminals on the Paraguana peninsula. This line will have two underwater crossings — one at the southern end of Tablazo bay and the other across the Gulf of Coro.

The refinery capacity of the country which now is about 350,000 B/D will be increased to about 450,000 B/D with the completion of Phillips plant at San Roque and the enlarging of Shell's refinery at Punta Cardon. In addition, Socony has recently purchased a refinery and terminal site near Puerto Cabello to handle the crude from that company's Barinas Field.

During the year a compromise agreement was arrived at between the operating companies and the labor unions. By the terms of the new contracts the operators' payrolls have been increased by about 10 per cent.

EUROPE

It is estimated that in 1951 Europe, including Russia, produced slightly over one million bbl of crude oil a day corresponding to less than 10 per cent of the total world production. Western Europe's share of crude production was less than one-half of one per cent of world production, nearly 50,000 B/D, taking care of only five per cent of Western Europe's consumption of 1,000,000 B/D. Although Western Europe's production is very small, an increase of 23 per cent in 1951 compared to 1950, is encouraging.

Of the western European countries which are producing crude oil, Germany was leading at the end of 1951 with 28,000 B/D, followed by the Netherlands with 14,000 B/D, and France taking third place with nearly 6,000 B/D. Great Britain contributed a little less than 1,000 B/D and Italy 250 B/D.

Western Germany

Western Germany's crude oil production of 28,000 B/D is supplying approximately one-third of its consumption. In order to stimulate domestic production the industry is protected by high tariffs allowing the producing companies a price of $6.00 a barrel. There are 10 major companies operating the 37 fields in Germany, among them Deutsche Vacuum, owned by Socony-Vacuum Oil Co., Inc., and Gewerkschaft Brigitta, owned by Shell Oil Co. and Standard Oil Co. (N.J.). These foreign-owned companies are producing roughly one-fifth of Germany's total crude oil. Germany's refinery capacity at present is nearly 115,000 B/D.

In Western Germany the bulk of the production is from Cretaceous and Jurassic sands in the northwestern part of the country. The Suderbruch Field, in the Hannover district, which was discovered in 1949 and located on an anticline between two salt domes, contributed about 2,000 B/D. In addition to the original middle Jurassic horizon, an upper Jurassic and a lower Cretaceous sand have also proved productive. Depths vary from 4,000 to 7,000 ft. The Eldingen Field, discovered in 1949, averaged 850 B/D from basal Jurassic sands. The Emsland district, on the Dutch border, continued to produce a large share, over 12,000 B/D.

Development drilling in the Suderbruch, Eldingen, and in the Emsland fields was particularly active.

Exploration drilling and other surveys are carried on in the four major prospect basin areas: Northwest German and Munster basins for Cretaceous and older prospects, the Rhine Graben and the Molasse Basin of Southern Germany for Tertiary and possibly Mesozoic prospects. Statistical data for 1951 show an increase over 1950 which was in the neighborhood of 1.2 million ft of drilling, approximately one-fourth of this for exploration, in addition to a total of 260 crew months of reflection seismograph, and 12 crew months of gravity meter surveys. An estimated total of 35,000,000 acres is covered with exploration concessions in Western Germany at present including areas applied for.

Encouraging oil indications were obtained in a well drilled by Deutsche Vacuum Oel A.G. on a joint prospect with Gewerkschaft Brigitta at Hemmelte 50 miles east of the Dutch border in the upper Jurassic at a depth around 4,000 ft. Initial production of the discovery well, Hemmelte-West No. 1, amounted to 8.5 bbl/hr (204 B/D rate) through a 4 mm (5/32-in.) choke.

Netherlands

In the bordering Netherlands, which are part of the same Northwest German basin, the Schoonebeek Field produced 14,000 B/D from lower Cretaceous sandstone at an average depth of about 3,000 ft. The oil is of low gravity and of the same type as the oil produced across the border in the German Emlichheim and Ruhlermoor fields. There are 120 pumping wells. The crude is competing with world prices. This production meets about one-fourth of the country's present consumption.

Both exploitation and exploration in the Netherlands is controlled by the Ned. Aardoolie Mij. (Netherlands Petroleum Co.) owned jointly by Shell and Standard of New Jersey. Their exploration area covers roughly 7,500,000 acres. Exploration was carried on with all methods as in previous years and has resulted in the discovery of natural gas in the area west of the Schoonebeek Field.

Gas has now been reported at six places. Further test wells are being drilled, some to 7,000 and 10,000 ft. The reports indicate that an annual output of 1,593,000,000 cu ft, equivalent to about 10 per cent in energy of the country's production of coal gas, can be relied upon.

It is said that N.A.M. plans to intensify its gas search and will spend $2.5 million for this purpose alone this year.

Denmark

Also in the same basin as Northwest Germany is a concession held by Danish American Prospecting Co., a Gulf subsidiary, covering all of Denmark. This concession covers

roughly 11 million acres of land plus the adjacent water areas and runs for a period of 50 years beginning in 1950.

Last year one deep wildcat rig was active in addition to one structure drill and one seismograph party, and the scale of activities is on the increase.

The first important oil indication was reported recently from a well in southern Jutland near Tondern at a depth of about 10,000 ft.

France

France's production more than doubled during 1951 as a result of the continued development of the Lacq Field, discovered in December, 1949. The production of 21.5° API gravity oil from the Lacq Field is from relatively shallow sands in the Cretaceous at a depth of 2,200 ft. The field averaged less than 5,000 B/D from 14 producers, all flowing. The balance of French crude was from the Rhine Valley fields at Pechelbronn. The St. Marcet Field continues to produce natural gas which is of local importance.

Exploration is being carried on primarily in the Aquitanian and the Rhone Valley basins of southern France. In addition to a French company holding about 7 million acres in the Aquitanian Basin, Standard Francaise de Pétroles is exploring a concession of over 4 million acres. In the Rhone Valley another French company holds 2.8 million acres and is active in exploration with all available methods.

Great Britain

Production in the United Kingdom remained steady at a little less than 1,000 B/D. The operation of secondary recovery by water injection has largely offset the normal decline.

Italy

Italy's production of crude oil is very small and estimated at 250 B/D. Refining capacity is 180,000 B/D.

The largest prospective basin in Italy is the Po Valley where at present exploration and exploitation are reserved to a government agency. The Cortemaggiore gas field is being developed in Tertiary sands at about 7,000 ft depth and has increased Italy's gas reserves. A natural gas system of S.N.M. consists of 675 miles of pipe line.

Eastern Europe

Information on eastern Europe is extremely limited. The following estimates appear to be the best available but may be far from accurate.

Austria

Austria's current production, all located in the Soviet zone, is estimated at 40,000 B/D. It is also estimated that the refineries in the Soviet zone have a combined throughput capacity of 20,000 B/D, and that Austria's total domestic consumption is about 17,000 B/D. Both Shell Oil Co. and Socony-Vacuum Oil Co. participate in producing and refining crude oil in the Soviet zone.

Exploration is reportedly carried on in the American and the British zones. One seismograph party is engaged in experimental surveys in Upper Austria for a company owned jointly by Shell Oil Co. and Socony-Vacuum Oil Co., Inc. Exploration rights in the Graz Basin on the Yugoslavian border has been granted recently to Van Sickle, a British concern which had been active in the original exploration in the Zistersdorf area.

Yugoslavia

Yugoslavia's oil industry is State controlled. The target for last year was a production of 9,000 B/D which is its present estimated domestic consumption. Actual production, however, is believed to have been not over 3,500 B/D. Refining capacity is 11,000 B/D.

Rumania

The oldest and still the largest oil producing area in Southeastern Europe lies in Rumania. Peak production was achieved in 1936 with 170,000 B/D. Present production is estimated to be about half this amount, *i.e.*, 85,000 B/D. Refinery capacity of 140,000 B/D indicates a considerable surplus capacity. Domestic consumption is estimated at 30,000 B/D. On the basis of present production estimates Rumania should have approximately 55,000 B/D available for export.

Hungary

The current estimated rate of 10,000 B/D more than covers inland consumption of 8,000 B/D. Refining capacity is around 23,000 B/D. Hungary is exporting petroleum products in exchange for some of the imports the country needs. A 10-year fuel saving plan was announced in April, 1951.

Poland

Poland's production is estimated at 3,500 B/D, refinery capacity 18,000 B/D, consumption 12,000 B/D. Exploration in the foothills of the Carpathians seems to have resulted in natural gas discoveries. Production of synthetic oil used to be 2,000 B/D and is probably being extended.

Czechoslovakia

Crude oil is produced in the northern part of the Vienna Basin which extends from Austria into Czechoslovakia. In addition to an indigenous crude oil production of approximately 2,000 B/D Czechoslovakia is said to obtain 5,000 B/D of gasoline and diesel oil from coal hydrogenation. Consumption of petroleum products has been reported at about 14,000 B/D. The balance of Czechoslovakia's demand must be met by imports.

Albania

Albania's crude production is reported to have increased, according to official statements, to three times its pre-war level of 2,700 B/D which would indicate a present production of 7,000 B/D. This crude is sent by tanker to Batum for refining. Albania's own demand of 1,000 B/D is satisfied mainly by imports of finished products pending the completion of a refinery building program.

Russia

Russia's production is estimated at between 800,000 and 900,000 B/D. Less than one-half is reported to be produced from the old fields in the Baku area, the balance increasingly from the area west of the Ural Mountains.

MIDDLE EAST

In Kuwait, a successful oil well has been drilled eight miles north of the Burghan Field. It is impossible to estimate what this well adds to the Burghan reserve, but it does appear that the Burghan Field or trend may extend northward and yield some important additional reserves. In the Peninsula of Qatar the present field at Duhkan is a long narrow anticline. Additional wells have been drilled to the south and a new wildcat is now in operation as a step-out of some 20 miles. If this well is successful it will make the Duhkan Field about 45 miles long.

Another significant development has taken place in Arabia. The Ain Dar Field was proven to be of major proportions some two years ago. The Uthmaniya wildcat, a location some

30 miles to the south of Ain Dar, was completed as a successful oil well early in 1951. Southward step-outs from Ain Dar and northward step-outs from Uthmaniya have now also resulted in successful completions, adding greatly to the probable productive territory of these two fields.

The production of the great Kirkuk Field in Iraq is shortly to be materially increased. During the early years a production of some 90,000 B/D was taken from this field and transported to the Mediterranean through two 12-in. pipelines. About one and a half years ago an additional 16-in. line was put into operation, permitting total throughput of about 165,000 B/D, which is the present production of the field. However, the pipeline system is to be increased with the completion of a new 30-in. pipeline which will transport over 250,000 B/D. This line will come into partial operation early in 1952 and will be completed toward the end of that year. With the new facilities, the Kirkuk Field will be able to produce 450,000 B/D by the end of 1954 and is scheduled for 600,000 B/D by the end of 1955. In Kirkuk itself a few new wells are being drilled which will permit oil to be produced from a wider area. Also nearing completion are additional pipelines and collecting stations, and additions to the de-sulphurization plant. It is expected that the Kirkuk Field will easily yield the increased production. The wells are very shallow and under certain conditions individual wells can produce as high as 20,000 B/D.

Middle East production amounted to about 2,000,000 B/D prior to the shutdown in Iran. To illustrate how rapidly events take place in this prolific area, Middle East production is now at almost the same figure in spite of the Iranian shutdown. The following figures indicate current production in the Middle East:

Area	B/D
Arabia	920,000
Kuwait	800,000
I. P. C.	160,000
Bahrein	30,000
Qatar	50,000
Basra	10,000
Total	1,970,000

FAR EAST

The Far East includes India, Pakistan, Burma, China, Japan, Russian Sakhalin, Borneo, Indonesia, New Guinea, Australia and the islands of the Pacific.

The Attock Oil Co. in Northwest Pakistan produces and refines for local consumption only 3,200 B/D. In Assam at Digboi, the Assam Oil Co. has increased its production over last year's rate to 5,300 B/D, which is produced and refined to supply indigenous markets in that area. Burma, although reports have not been confirmed, produced approximately 3,000 B/D from the old fields along the Iriwaddie River, which was barged to local markets and refined at skimming plants. However, the Burma Oil Co. has made progress in its negotiations to re-enter the fields and place this important area on production.

There are still areas in Indonesia which have not been rehabilitated or returned to the original owners since the Japanese occupation. One of the important areas is North Sumatra where a very fine quality crude oil was produced and refined in the Pankalan Brandan refinery now destroyed. The Shell Oil Co. is the owner and is now negotiating for the return of this property. It is reported that approximately 300 B/D is being produced and refined by skimming methods in teakettle-type small refineries and sold in the small market places. Mid-Sumatra at present is not producing. However, very substantial reserves have been developed; the most important of which is the California-Texas Co.'s Minas Field which is reported to have reserves of a half-billion barrels. This company is now constructing a pipeline to a river terminal outlet and the area should be on production by mid-1952.

Standard-Vacuum Oil Co. also has holdings in Mid-Sumatra and has plans to develop and place on production. South Sumatra, the most important producer in Indonesia today, produced at the rate of 121,000 B/D. Two companies are the major operators in this area: BPM (Shell) and Standard-Vacuum Petroleum Maatschappij. Development continues to be carried out in this area which has had a remarkably stable atmosphere as compared to the remainder of Indonesia which is now going through all of the growing pains of a new republic. Indonesia produces approximately 149,000 B/D. This does not include New Guinea which is still under Netherlands control. Of this, as stated before, Sumatra produced 121,000 B/D, Java produced 12,400 B/D during 1951 as compared to 8,400 B/D the previous year. That portion of Borneo which is part of Indonesia produced 15,100 B/D during the year which is slightly under the 1950 figure of 16,231 B/D. Netherlands New Guinea produced approximately 5,000 B/D from the Klamono Field in Western New Guinea, and development has progressed in Eastern Vogelkop Area and to the extent that plans are now being considered for a pipeline outlet in order to place this area on production. British Borneo produced at the rate of 102,500 B/D which is increased over 1950 production of 84,800 B/D, the Seria Field being the most important producing area.

Based on fragmentary reports, it is estimated that the Kan-u Field in China continues to produce 2,000 B/D which is utilized in local markets.

Formosa continues to produce about 75 B/D. There is no production in the Philippines; however, exploration continues.

Japan increased from 5,600 B/D in 1950 to 6,500 B/D in 1951 as a result of the development of some deeper zones in the existing fields in the Akita Area. From partial reports it is estimated that the Russian-held Sakhalin produces about 9,000 B/D.

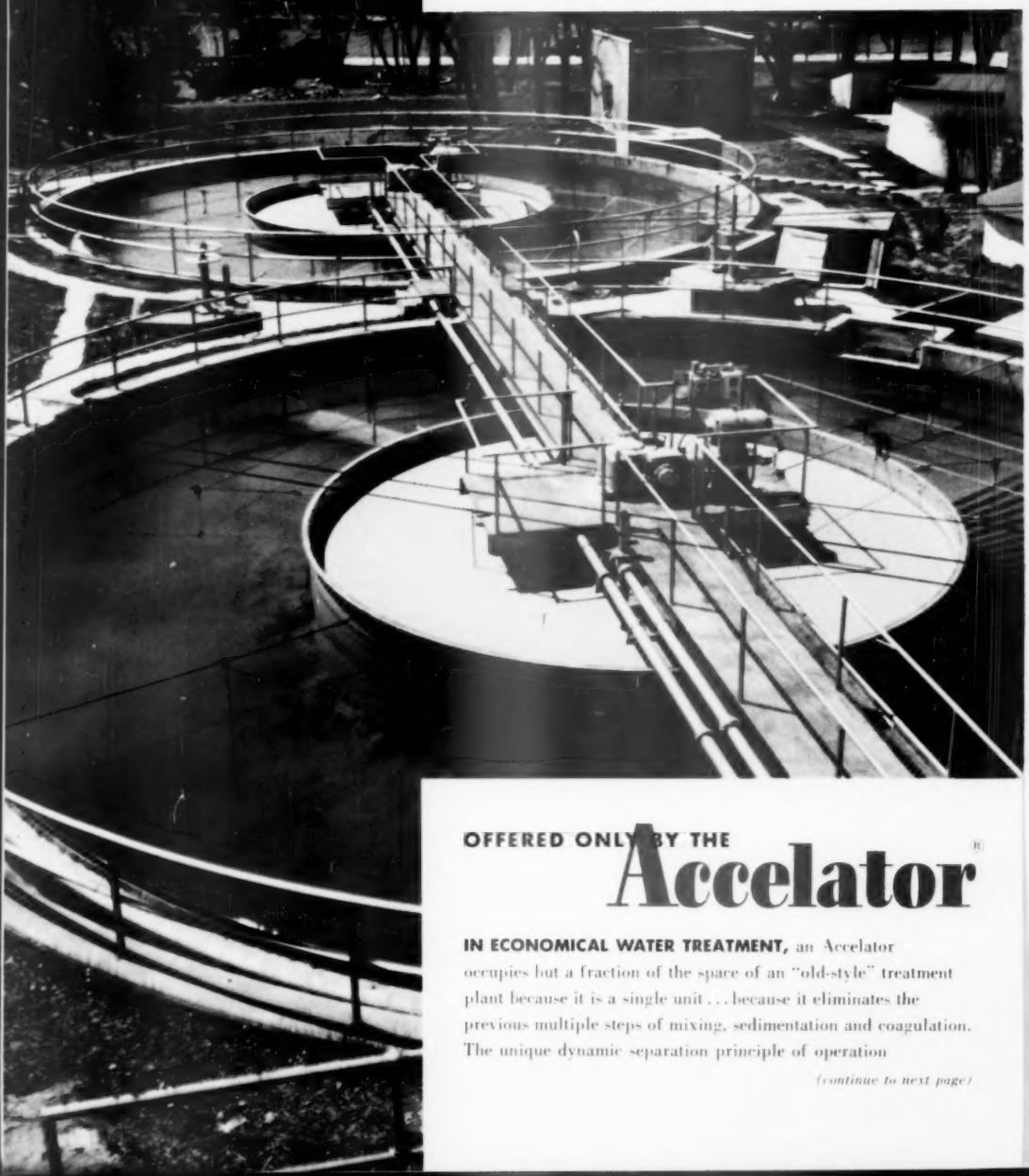
Of the development in this whole area, there were 33 rigs utilized over the Far East; there were 150 wells drilled, of which 28 were dry holes. Of exploration, 28 rigs were utilized in the Far East, 34 wildcat wells which resulted in 5 discoveries; four in Indonesia, South Sumatra, and one in Netherlands New Guinea. Extensions to established production in Indonesia and Japan were made as a result of exploration drilling. The geological effort was 292 geological party months in the entire area mostly concentrated in Indonesia and in Netherlands New Guinea and Papua. Some work was being done in India and in the Philippines. The geophysical effort of 1951 included 191 gravity meter party months mostly concentrated in New Guinea, Australia, Sumatra and India. There, seismograph effort was 129 party months in 1951 and that was concentrated for the most party in Indonesia and New Guinea with a certain amount of work being done in Papua.

On the whole, the political situation in the Far East holds back developments. However, they are reasonable people and it is hopeful that they will come out with a reasonable solution to their many political problems.

In Australia, the California-Texas Co. group, plus some local capital, are drilling on the West Coast of Australia. The Australian Government is in the desert basin area and will start drilling in 1952. The Philippine Government, plus private interest, operate two wildcat strings, drilling two unsuccessful tests in 1951. ★ ★ ★

Dynamic Separation saves Money

INFILCO
* BETTER WATER CONDITIONING * AND WASTE TREATMENT SINCE 1914



OFFERED ONLY BY THE

Accelator®

IN ECONOMICAL WATER TREATMENT, an Accelator occupies but a fraction of the space of an "old-style" treatment plant because it is a single unit . . . because it eliminates the previous multiple steps of mixing, sedimentation and coagulation. The unique dynamic separation principle of operation

(continue to next page)

(from preceding page)

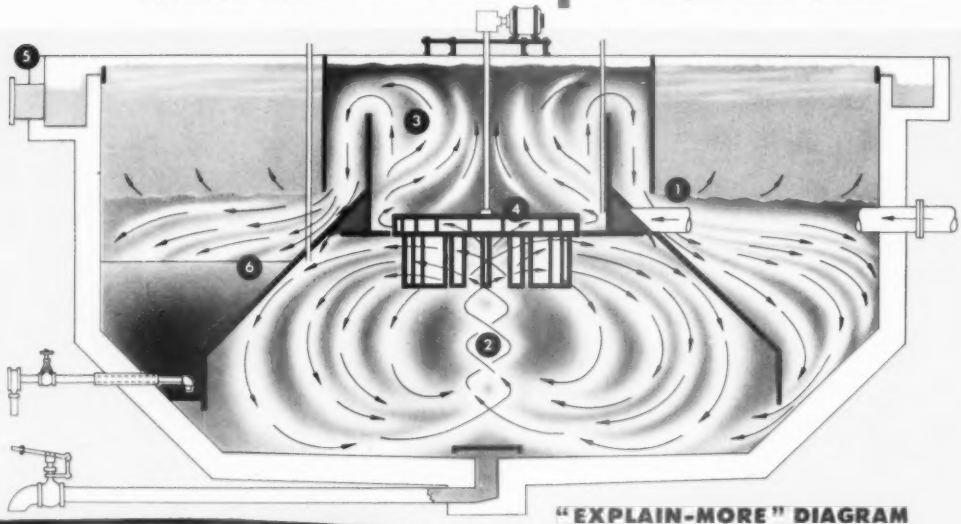
INFILCO
BETTER WATER CONDITIONING AND WASTE TREATMENT SINCE 1934

permits the treated water to separate from the top of a downward-moving pool of uniformly sized slurry in contrast to having the treated water filter upward through a suspension of sludge of gradually decreasing particle sizes.

INFILCO INC. ★ *Tucson, Arizona*

Outstanding advantages—based on more than two thousand Accelator efficiency-of-operation reports:

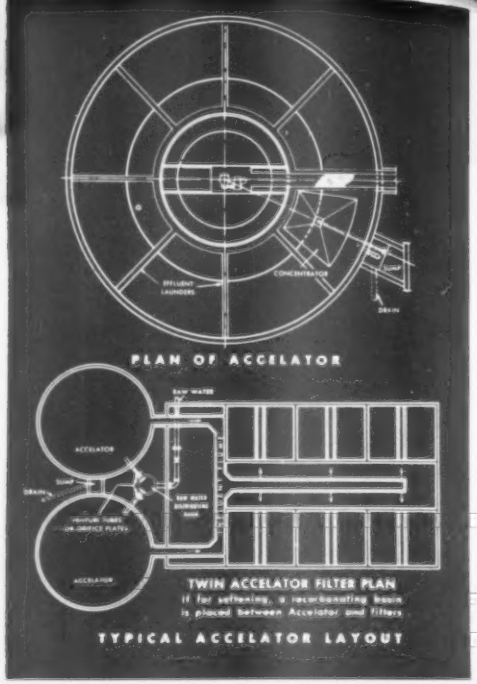
- ★ Faster separation of solids from treated water
- ★ Low-velocity movement of tremendous quantities prevents floc break-up
- ★ Rapid mixing of incoming water and chemically impregnated slurry
- ★ Small or large flows have complete contact with slurry
- ★ Thickened sludge is automatically drawn off
- ★ Settling-out of solids is prevented



"EXPLAIN-MORE" DIAGRAM

the Accelator basin contains:

1. A raw water inlet and distributing duct
2. A primary mixing and reaction zone
3. Two concentric draft tubes which form the secondary mixing and reaction zone
4. A rotor-impeller for mixing and pumping, driven by a motorized reducer
5. An effluent launder system
6. Concentrators to accumulate and remove excess slurry



SUGGESTED ACCELATOR APPLICATIONS / POSSIBLE TREATMENT REQUIREMENTS → / WATER END-USE	SOFTENING	CLARIFICATION	STABILIZATION	ALKALINITY REDUCTION	ORGANIC MATTER REMOVAL	TASTE AND ODOR REMOVAL	COLOR REMOVAL	IRON REMOVAL	SILICA REDUCTION	NEUTRALIZATION
MUNICIPAL	X	X		X	X	X	X	X		
PULP	X	X		X	X		X	X		
PAPER	X	X		X	X		X	X		
BEVERAGES		X		X	X	X	X	X		
COOLANT	X	X	X	X	X			X		
BOILER FEED	X	X		X	X		X	X	X	
RAILROADS	X	X					X			
TEXTILE	X	X			X		X	X		
CANNERIES		X		X	X	X		X		
BREWERIES		X		X	X	X	X	X		
OIL FIELD FLOODING		X	X		X		X	X		
BRINE DISPOSAL		X	X		X		X	X		
INDUSTRIAL WASTES DISPOSAL AND REFUSE		X	X		X		X			X

Weather and Oceanographic Problems In the Petroleum Industry

By A. H. Glenn
Member AIME

The petroleum industry goes where oil occurs, whether it be atop rugged mountain ranges or below the surface of the seas. In most cases, the weather plays an important role in recovery and dispersal practices applied when oil is found and piped to refineries.

INTRODUCTION

During the past 10 years the petroleum industry has been expanding rapidly to meet a major increase in demand for products. This expansion, carried on during periods of manpower and materials shortages, has required maximum efficiency in the exploitation of existing resources, and a vigorous campaign to locate and develop new resources. In such an unprecedented program of increasing production under adverse economic conditions certain problems, formerly considered of negligible importance, have become particularly troublesome. One such group of problems is the weather and oceanographic difficulties that are encountered through the gamut of petroleum operations, from exploration to the delivery of products to the consumer. Experience acquired in working on these problems during the past six years indicates that the amount of money involved in correct decisions *vs* incorrect decisions where weather and oceanographic conditions are a factor, is of significant economic importance. This paper endeavors to indicate the economic scope of the weather and ocean problems in the petroleum industry, and summarize some experience gained in attempting to arrive at an efficient method of attacking these problems.

SCOPE OF WEATHER AND OCEAN PROBLEMS

The following list enumerates some problems that have arisen during the past several years. The list is broken down into categories according to the departments in which the project was carried on.

1. Production:
   a. Design studies for coastal and offshore facilities.
   b. 48-hour operational weather and sea forecasts for planning and safety in offshore construction, drilling and production.
   c. Weather and oceanographic instrumentation for developing design data for coastal and offshore drilling.
   d. Hurricane evacuation problems.
   e. Radar weather warnings (line squalls and northers).
   f. Study of feasibility of operation of amphibious planes to offshore sites.
   g. Economic comparison of wind driven generators *vs* gasoline motor generators.
   h. Study of feasibility of barging cargo offshore *vs* cost of dredged channels.
   i. Study of frequency of low tides interrupting navigation in shallow channels.
2. Exploration:
   a. Wave and weather planning studies for foreign and domestic exploration campaigns.
   b. 48-hour operational wave and weather forecasts for coastal and offshore exploration.
3. Legal:
   a. Compilation of weather data used in Workmen's Compensation litigation.
   b. Determination of effect of wind in changing tide levels in tideland boundary disputes.
   c. Preparation of bibliographies of scientific papers.
4. Pipeline and Refinery:
   a. 48-hour operational forecasting for scheduling construction of offshore pipelines.
   b. Hurricane shutdown problems at refineries.
   c. Wave forecasting and design problems at exposed tanker terminals.
   d. Design studies for offshore pipelines.
   e. Precipitation and temperature forecasting for inland pipeline construction, maintenance and operation.
   f. Air pollution problems.
   g. Soil temperature studies affecting construction and design of pipelines.
5. Aviation:
   a. Ceiling and visibility forecasting.
   b. Wave forecasting for amphibious aircraft.
6. Marketing:
   a. Temperature data for natural gas marketing.
   b. Temperature studies for estimating fuel oil consumption.
7. Research:
   a. Oceanographic data employed in recent sedimentation studies.
   b. Study of anomalous radar propagation for horizontal control in geophysical surveying.
   c. Oceanographic data used in pipeline fouling and corrosion problems.
   d. 48-hour operational forecasting for scheduling research field work.
8. Tanker Operation:
   a. Selection of ocean routes for most favorable current and wind conditions.

This paper was presented at the Petroleum Branch, AIME, Fall Meeting in Oklahoma City, Oct. 3-5, 1951.

COST CONSIDERATIONS

In attempting to estimate the cost of the effect of favorable or unfavorable weather or sea conditions, one finds that relatively few quantitative records exist. To give an idea of cost considerations, some examples are included. These do not begin to afford an estimate of the overall problem but serve to provide specific cases in lieu of generalities.

Referring to the problem of forecasting seasonal demands for petroleum products, C. C. Brown has pointed out that "one factor that could throw these figures pretty badly off would be warmer than normal weather." Since data similar to these compiled by Brown are used in making decisions affecting large operations, certainly a large sum of money is involved here. J. A. Cogan has confirmed Brown's conclusion with examples of the effect of the abnormal winter weather of 1947-1948 and 1948-1949 on the industry.

J. E. Graham and R. A. Geyer, in evaluating work done by A. H. Glenn and Associates for offshore operators on the Louisiana coast, showed how $25,000 was saved through improved planning in 12 weather situations where hurricane evacuation and chain-laying problems arose.

Glenn and James, in a study of the effect of wave action on offshore gravity meter exploration, showed how decisions made in scheduling could vary costs of reconnaissance surveys by 50 per cent.

GOVERNMENT SERVICES CURRENTLY OFFERED INDUSTRY

It is apparent that weather and ocean conditions affect the petroleum industry to a significant extent, dollarwise. The question then arises . . . what can be done to minimize losses suffered through action of the elements? One opinion, frequently expressed, is that nothing can be done. Others, while not so pessimistic, feel that the petroleum industry has pretty well exhausted the possibilities in the use of meteorology and oceanography. This pessimism stems, partially, from an assumption that the governmental services currently provided industry, represent the best that can now be offered by the weather science, and from a lack of understanding of meteorology and oceanography, and the many theoretical and instrumental techniques and the vast amount of data, these sciences have to offer.

The government weather service is somewhat conservative where the adoption of new developments in the field of meteorology are concerned. To illustrate this point, following is a post-flight summary of a hurricane reconnaissance flight flown by an Air Force B-29 during the late morning and early afternoon of September 6, 1951. This dispatch was relayed over government weather teletypes at approximately 2:30 p.m., CST, Sept. 6.

Post Flight Report

Hurricane Easy was located by dead reckoning and the center fixed by radar at 22 degree 30 min north latitude 61 degree 10 min west longitude at 06/1406Z. The center of this storm is 70 miles in diameter. Max. winds of 110 knots were observed in north east quadrant and extend for 100 miles. The minimum pressure was 967 MB at the surface. The eye is circular and is well defined and the storm itself is characterized by bands of intense precipitation and heavy rain. 6 such bands were encountered entering the eye from the south east and 4 were observed leaving toward the north east. By quadrant: winds of 110 knots extend 120 miles to north east, winds of 80 knots extend 100 miles to northwest, and winds of 60 knots extend 80 miles to south east and 50 miles to south west. Ceilings are variable from 2/5 hundred feet and there is varying intensity of rain from light to moderate. Moderate to severe turbulance is prevalent throughout the entire storm. Overall size of storm is 210 miles long by 140 miles wide. Movement of storm is generally westerly at about 14 knots. This storm is particularly intense and gives indications of intensifying even more and becoming extremely broad in the area over which it will affect.

Next follows the government hurricane advisory publicly issued at 4 p.m., CST, Sept. 6.

Advisory Number Eight Easy 5 pm EST Sept 6 1951
The hurricane is increasing slowly in size and intensity stop At five pm EST . . . 2200Z . . . the center was near latitude twenty two point six north longitude sixty two point four west of about four hundred miles northeast of San Juan Puerto Rico stop It is moving westnorthwestward at fourteen or fifteen mph with speed tending to slow down stop Highest winds estimated above one hundred forty mph near center and lowest pressure twenty eight point twenty six inches stop Winds of hurricane force extend fifty miles from center in southern semicircle and eighty to one hundred miles in northern half stop
This is now a large and dangerous hurricane and further intensification is indicated stop Ships should avoid it stop

Obviously far more specific data regarding this hurricane were available than were publicly released. This is customarily the case even when industry needs all data available concerning a nearby hurricane. The government weather service is not organized to digest and distribute all the data available.

In addition to the inability of the government weather service to devise methods of making weather data available to the petroleum industry, they have not been successful in incorporating new forecasting techniques into their service. For example, the government service has received routine reports from five weather radar stations along the western Gulf for the past year. Use of these radar sets and other available data would permit accurate two to three-hour warnings of the dangerous line squalls which result in equipment damage (boats and barges forced aground, etc.) in coastal oil fields on the western Gulf annually. But such a service is not in existence and there is no indication that it will be. When we inaugurated a radar storm warning service for our clients in 1948, many oil company personnel were not aware that such warnings were possible, yet the technique was developed five years earlier in 1943.

Other examples can be cited showing the five to 10 year lag between the development of economically valuable weather and oceanographic data or techniques, and their incorporation into the government service. This time lag promises to become greater since research funds are increasing and the funds for non-defense government agencies are not. Evidently, if industry wishes to solve its own weather and oceanographic problems, it will have to solve them as it has solved its other problems; that is, by its own efforts, with its own money, under the stimulus of the competitive enterprise system.

AN EFFICIENT APPROACH TO WEATHER AND OCEANOGRAPHIC PROBLEMS

There are many weather problems which have already been solved successfully by the petroleum industry and others which have not. A resumé of some experience in handling such problems may, therefore, be appropriate.

The first step in solving any problem involving the effect of the elements on petroleum operations is to define the effect quantitatively. This may seem to be a rather elementary statement, but many of the failures to solve major problems can be traced to an attempt to circumvent this step. For example, efforts to solve the problem of estimating fuel oil consumption have sometimes started with the subscription to a long-range temperature forecasting service. The assumption was that if the meteorologist could predict the temperature accurately a month or so in advance, the future fuel oil consumption could be estimated. This approach to the problem has not been very successful. There are several reasons, but initially, even if it were possible to predict the temperature within one degree, hour by hour for the entire approaching winter, at a number of locations in the United States, the forecast would still be of limited value, because an accurate relationship between temperature, weather, and fuel consumption has not been worked out (the "degree-day" relationship provides only a gross first order approximation). The first step in solving this weather problem would be to study quantitatively what happens to fuel consumption when temperature rises and falls, what happens when it rains, what effect does the wind have, etc. Once the quantitative relationship between several elements is known, the way is open toward a solution of a problem involving them, but not until then.

CLOSE LIAISON BETWEEN COMPANY AND CONSULTANT ESSENTIAL

Next, it should be emphasized that in solving industrial weather problems it is essential that the meteorologist or oceanographer work in close contact with the actual industrial problem. Costly mistakes have resulted from the misinterpretation of weather information. On one occasion, for example, we were furnishing hurricane information to an offshore operator. Included in the advisory was a statement that waves would increase to 15 ft off the Western Louisiana coast that night. An exploration executive who was receiving our advisories "through channel-" misinterpreted this statement to mean that the *tide* would rise 15 feet. He had some boats operating in an area of low elevation and had them moved, despite the fact that they were entirely safe. A 15-ft tide did not develop and several crew days were lost unnecessarily. Incidents of this nature have occurred which would have been avoided had the meteorologist been able to work directly with the company personnel.

INCENTIVE CONSIDERATIONS

Meteorologists working on company problems must have their interests directly involved in the successful solution of the problem. The meteorologists are similar to other professional men in that they do their best work for those who pay them. Our national weather service is administered on the socialistic concept that a scientist whose income is derived from the Federal treasury will work as conscientiously on a client's problems as a scientist paid by the client. The result of this thinking is that after 80 years of a complete monopoly of socialized meteorology, many industries are turning to private meteorologists . . . a notable tribute to the principles which American industry has been attempting to impress on the public mind.

COST OF METEOROLOGICAL AND OCEANOGRAPHIC SERVICES

This brings us to a consideration of the cost of solving weather or oceanographic problems. As a general statement, there is no weather or oceanographic problem encountered in industry for which some solution, partial or complete, cannot be devised. The economic question which arises is: what is the cost of the solution compared to the cost of the problem. An example was mentioned earlier where a client saved $25,000 in hurricane evacuation costs through the use of weather information which would not have been available to him except through a consulting meteorologist. There are other possibilities such as this where a few hundred dollars worth of consulting services enables the client to take advantage of existing data or techniques with resulting savings.

There are other instances where data must be acquired or techniques developed. Here the cost of consulting services runs higher. There are cases where oil companies have spent over a million dollars in developing weather and oceanographic data to solve a specific problem. In such situations, costs have frequently been borne by several companies having the common problem.

NATURE OF THE SOLUTION OF WEATHER AND OCEANOGRAPHIC PROBLEMS

The nature of a solution to a weather problem should be considered. One hears criticism of meteorologists for their failure to develop a perfect forecast. By the same process of reasoning, the petroleum engineers should retire to the laboratories because they can not guarantee that the pipe will not get stuck in the hole, and the geologists should bow out gracefully for not having been successful in developing a foolproof forked stick for discovering commercial producing areas. In other words when we attempt to solve a specific industrial weather or oceanographic problem we do not approach it with the attitude that we will find a cure all, or a final answer. Instead we strive to apply meteorology or oceanography in a way that achieves a better-controlled cheaper operation. The solution will practically never be only a "better weather forecast." More likely it will be a more efficient way of integrating weather information into company operations, or the incorporation of recently developed scientific techniques into company operations, or improved long-range planning of company operations through recent developments in the science of climatology, etc.

CONCLUSIONS

In summarizing the various pitfalls to avoid in attacking weather and oceanographic problems, it is not intended to leave the impression that the history of these problems in the oil industry is a series of mistakes and failures. On the contrary, the oil industry is several years ahead of the other American industries in applying meteorology and oceanography. Most of the major oil companies and a number of the independents have made use of consulting services in these scientific fields continuously for the past few years, and these services, once looked upon with skepticism are now considered an integral phase of oil operations. As with all engineering developments, there is room for improvement in present services furnished, and a widening horizon for new applications.

★ ★ ★

OUR "LABORATORY" EXTENDS OVER THOUSANDS OF MILES

Every oil field in the free world is in a sense an extension of the big Halliburton laboratory in Duncan.

Each has contributed to the vast store of knowledge that directs the design of Halliburton cementing equipment and every detail of Halliburton procedure.

Each has added to the tremendous total of cementing jobs successfully completed by the Halliburton organization—a total that exceeds the million mark.

Each has helped us to render constantly improved service at an average cost that is actually less today than in 1924.

Erle P. Halliburton

Chairman of the Company

HALLIBURTON OIL WELL CEMENTING CO.

Duncan, Oklahoma

Tools and Techniques for Directional Drilling

Reported by J. A. Klotz
Pacific Technology Group

A talk by Gordon Jackson, vice-president of the Eastman Oil Well Survey Co., entitled "Recent Development in Tools and Techniques for Directional Drilling," began the 1952 program for the Pacific Technology Group in Los Angeles, Calif. For the remainder of 1952, the Pacific Petroleum Chapter plans to present a series of lectures, with the continuity of a college course on the "Elements of Petroleum Production." The series, under chairmanship of S. T. Yuster, will consist of ten lectures presented by authorities on the following subjects: petroleum geology, petroleum prospecting, core analysis, well logging, reservoir fluids, fluid mechanics, solution gas drive, gravity drainage, natural water drive, and condensate production.

Jackson confined his talk to sidetracking in hard formation, slim hole wells in the Mid-Continent and Rocky Mountain areas. He gave a review of the economics of sidetracking; discussed three technical factors that influence sidetracking jobs; and presented current methods of whipstocking a rathole away from the original hole and of reaming the rathole to gauge.

Directional drilling was first used economically in California and reached its highest perfection there about 1947. California operators, however, are not as familiar with sidetracking as are Mid-Continent and Rocky Mountain operators. During the next year, 3,000 drilling rigs will operate in this country and will require sidetracking operations costing an estimated six million dollars; in addition, many wells that could be economically sidetracked will be abandoned because proper cost analyses are not available to show the advantages of sidetracking. Improvements in sidetracking methods would yield a great saving to the oil industry both directly by reducing the cost of each sidetrack job and indirectly by increasing the economic feasibility of a sidetrack job in each well.

Three factors that influence sidetracking in the Mid-Continent and Rocky Mountain areas are formation, hole size and cement plug. In these areas, formations are hard; they drill at rates of three to four in. per hour; normal bit life is four to five ft. Drilling costs are high and sidetracking is more attractive than it is in areas of rapid drilling and low hole cost. At present, Mid-Continent operators are allotted casing by weight rather than by length of pipe. These operators increase the total length of casing they can obtain by buying smaller sizes. Hole size is usually 5 to $6\frac{1}{8}$ in., and trouble that requires sidetracking is encountered below 5 or $5\frac{1}{2}$-in. casing. One recent job was successfully performed in $5\frac{1}{4}$-in. hole at 14,000 ft. The third factor, the competence of the cement plug, is unknown until the sidetrack attempt is well underway. Cement plugs are never as hard as the formation rock in these wells, but the plugs must be sufficiently competent to hold the whipstock during rathole drilling. About one-fourth of the cement plugs set before sidetrack jobs are unsatisfactory. Addition of sand and of chemical accelerators has become popular recently and may increase the probability of good cement plugs. Common practice is to add about 10 per cent sand to the cement slurry; rounded grain Ottawa sand, as used in Hydrafrac, is used because it causes less wear of cementing pumps.

Each sidetracking job can be divided into two distinct steps: (1) deflecting a rathole away from the cement plug that fills the old hole, and (2) reaming the rathole to gauge. Because currently used reamers do not ream these hard formations effectively enough to straighten the dog legs caused by whipstocking, much trouble occurs during reaming rather than during ratholing. Most of the recent improvements are directed toward improved means of reaming holes to full gauge.

After the rathole bit has passed the bottom of the whipstock and is drilling in virgin rock, drill string buckling caused by excessive weight on the bit and guided by side pressure of the bit against the formation, causes the bit to turn into the cement plug. This prob-

KANSAS SECTION OFFICERS for the coming year are, L to R, standing, E. S. Arnold, Phillips Petroleum Co., Eastern Kansas vice-chairman; J. W. Meyers, Champlin Refining Co., Western Kansas vice-chairman; G. J. Decker, Schlumberger Well Surveying Corp., Wichita vice-chairman; and seated at right, L. W. Holsapple, Sinclair Oil Co, chairman. Seated at left is G. L. Yates, outgoing chairman of the section.

lem was first overcome by drilling with diamond core heads rather than with ordinary rock bits. Diamond bits drill with less weight and thus with less drill string buckling. The tendency for the bit to deflect back into the old hole is minimized. Diamond bits are also more effective because they cut perpendicular to the well bore more effectively than roller bits. Additional improvements to overcome the tendency to fall back into the old hole caused by drill string buckling include whipstocks with low deflection angles ($2\frac{1}{2}°$) to reduce dog leg sharpness; full hole diamond bits (not core heads) designed specifically for sidetracking; and a knuckle joint bit and reamer set that allows the rathole to be deflected well away from the old hole before contact between the top of the dog leg and the drill string causes buckling.

Another problem arises during the reaming operation after the deflection tool has been run. Two new reaming tools have been developed to guide the reaming bit into the hole drilled by the deflection tool. The first consists of a stiff hollow guide pin that hangs through the center of a core bit and is fastened in the bit with a ball and socket joint; reaction of mud jetting from a hole in the side of the pin forces it against the side of the well hole. Inflexibility of the guide pin forces the core bit to follow the pin into the rathole. The second tool consists of a long, more flexible, guide tubing run loosely through a core bit. Again, a mud jet forces the guide tubing off center and allows it to be dropped into the rathole. The core bit then follows the curve of the guide tubing into the rathole much as a wash-over tool follows a fish. Two advantages of this tool are simplicity and ability of the second bit to be guided all the way to the bottom of the hole drilled by the first rathole bit.

Jackson concluded his talk with the remarks that, in the past 15 years, improvements have been made in many phases of ordinary directional drilling, penetration rates, accuracy and dependability of direction measurement, and dependability of deflection tools. In 120 sidetracking jobs, however, in the last 18 months, 24 jobs were not completely successful — four failed to sidetrack entirely, 20 extended beyond the limit of economic operation, and 96 were successful. Before this record can be improved, operators must anticipate each sidetrack job before the need for it becomes acute, so that the job can be planned as completely as other directional drilling jobs are planned. ★ ★ ★

PETROLEUM SCHOLARSHIPS were presented Texas A & M students for their leadership, character, good citizenship and outstanding scholastic achievements. The awards were made by the Standard Oil Co. of Texas and the Magnolia Petroleum Co. L. to R. are W. M. Sargent of Fort Worth; John Domercq, Jr., vice-president of the Standard Oil Co. of Texas; Julian C. Herring of Abilene; Baxter D. Honeycutt of Pickton and D. V. Carter, chief petroleum engineer of the Magnolia Petroleum Co. Sargent, Honeycutt and Herring, the winners, are senior petroleum engineering students.

Canadian Oil and Pressure Buildup Discussed at Mid-Continent Meetings

Reported by W. B. Davis and Fred Miles

The Western Canadian Oil Industry was the subject of a symposium at the regular meeting of the Mid-Continent Section last month. The section's Study Group members heard A. F. Van Everdingen of the Shell Oil Co., Houston, present a paper on the theory of "Pressure Buildup in Oil Wells," at an earlier meeting.

First speaker on the Symposium was John Arps, assistant to the executive vice-president of the British-American Oil Producing Co., who discussed the Athabaska Tar Sands in northern Alberta. Arps pointed out that the oil reserves of these tar sands could be as much as 300,000,000,000 bbl. Up to the present time, their isolated location and the necessity of mining them have made recovery of this oil uneconomical. It is possible that increases in the price of crude oil or improvements in recovery techniques will make this enormous oil reserve available in the future.

V. M. Brant, assistant manager of exploitation of the Canadian Gulf Oil Co. in Calgary, discussed current drilling and production practices in Western Canada and compared them with like operations in the United States. He pointed out that in general operations in Western Canada are very similar to those encountered in the Mid-Continent area, except that the extremely cold winters necessitate the use of a great many protective measures not commonly found in the Mid-Continent.

The third speaker was W. B. Davis, a staff assistant with the Gulf Oil Corp. in Tulsa. He discussed Alberta proration and outlined the characteristics of some of the larger new Western Canadian oil reservoirs.

E. W. Brake, chief engineer of the Tulsa division of the Gulf Oil Corp., acted as moderator.

Van Everdingen's talk at the study group meeting dealt with the physical concepts involved in the determination of pressure buildup and pressure drawdown in well bores. He described a series of equations derived from the basic physical concepts by means of the La Place transformation and demonstrated how the equations could be employed in determining apparent effective permeabilities and static reservoir pressures. In addition, he discussed the use of these relationships in determining skin effect and showed how the efficiency of well completions within a common reservoir may be determined by utilizing skin effect determinations. He also showed how negative skin effects may be anticipated after hydraulic fracturing or acidizing. ★ ★ ★

AIME President Tours Texas Local Sections

PRESIDENT HAIDER, right, presents the AIME Certificate of Honorary Membership to E. DeGolyer at North Texas Section meeting in Dallas.

Michael L. Haider, 1952 AIME president, visited and spoke to five local sections and three student chapters of the AIME in Texas last month in a five-day whirlwind tour of the state.

President Haider, who is deputy coordinator of producing activities for Standard Oil Co. (N.J.), was accompanied by AIME Directors W. S. Morris, vice-president and general manager of the East Texas Salt Water Disposal Co.; Carl E. Reistle, Jr., director and manager of Humble Oil and Refining Co.; Harold Decker, president of the Houston Oil Co.; and AIME staff members Joe B. Alford, Petroleum Branch executive secretary; and Jess E. Adkins, editor of the JOURNAL OF PETROLEUM TECHNOLOGY.

The tour began in Dallas with the first stop being Lubbock and the student chapter at Texas Technological College. There followed stops at the Permian Basin Section in Midland; the student chapter at Texas A&M College at College Station, the Gulf Coast Section in Houston, the Southwest Texas Section in Corpus Christi, the student chapter at the University of Texas at Austin, the North Texas Section in Dallas and the East Texas Section in Kilgore.

In his talks to local sections, President Haider pointed out that during 1952 the AIME membership will be given an opportunity to vote as to whether it wishes to retain the present $20 dues level or revert to the $15 level of three years ago. (The 1952 referendum is mandatory under the provisions of the rise in dues voted in 1950.) President Haider pointed out that if present services are to be maintained by the Institute, the present level of dues must be maintained.

"The question naturally arises as to the Institute's financial situation and whether it can be maintained on a $15 per year dues level," he said. "I think the answer is that it can but it cannot give the services it now renders.

"Last year the total income of the Institute was $522,076 or $26.47 per member and expenditures were $514,067 or $26.03 per member," he explained. "(This represents) a surplus of $8,009. In 1952, it is estimated income will be up $23,000 but expenditures are also estimated to increase $25,000 so that a surplus of $6,000 will result.

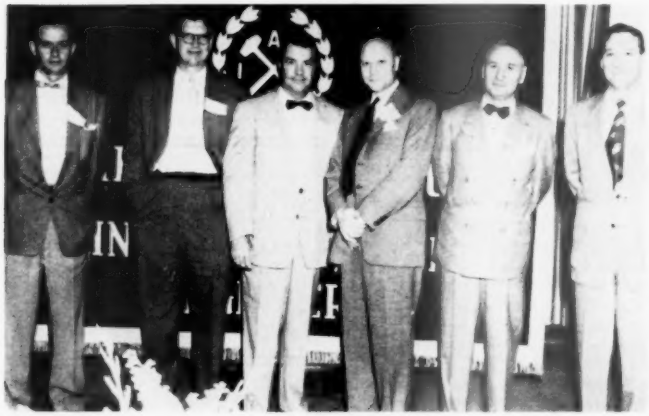
"The year 1951 is the first in which there was a surplus since 1942. In the 10-year period from 1941 through 1950 the total deficit was $206,428, which was offset by drawing on various special accounts and funds. These have now been practically exhausted and it is therefore essential that current income not only be sufficient to pay current expenses but that it also provide a surplus with which to rebuild these special accounts," he said.

Interest in the dues level was manifested at the various meetings by questions from the members attending. At all stops, President Haider welcomed questions from the members.

At the student chapter meetings, he stressed the importance of engineers in industry and pointed out that "there is a critical dearth of engineering students in schools today," and urged students to continue their studying following graduation and their entry into industry and to spend their present time in the establishment of a firm foundation of engineering knowledge.

In Dallas before the North Texas Section meeting, the AIME president presented the AIME Certificate of Honorary Membership to E. DeGolyer (Member, '14) of the firm of DeGolyer and MacNaughton, consultants. The certificate had been awarded *in absentia* to DeGolyer at the AIME Annual

Continued on Page 7, Section 2



AIME PRESIDENT AND DIRECTORS at the Southwest Texas Section meeting last month. They are, L. to R., Carl E. Reistle, Jr., AIME director; Harold Decker, AIME director; Harry Vaughan, Southwest Texas Section chairman; Michael L. Haider, AIME president; W. S. Morris, AIME director; and Paul R. Turnbull, Petroleum Branch AIME chairman.

Professional Services

This space available only to AIME members. Rates upon request.

AMSTUTZ AND YATES, INC.
Petroleum Engineers and Geologists
Estimates of Oil & Gas Reserves
Property Valuations, Reservoir Analyses
Geologic Investigations
405 KFH BLDG., WICHITA 2, KANS.

BERGER AND PISHNY
Consulting Geologists and Engineers
901 Commercial Standard Bldg.
Fort Worth 2, Texas
Walter R. Berger — Chas. H. Pishny

JOHN G. CAMPBELL, CHEMIST
Licensed for
Fluorometric Analysis of Well Cuttings
Podbielniak & Charcoal Analyses
Waters - Oil Field Brines - Cores
CORPUS CHRISTI, TEXAS — PHONE 4-5612

CHEMICAL & GEOLOGICAL LABORATORIES
Consultants - Investigations - Evaluations
James G. Crawford — *Chemical Engineer*
H. E. Summerford — *Petroleum Geologist*
F. Raymond Wheeler — *Petroleum Engineer*
P. O. BOX 279 — CASPER, WYOMING

CRUTCHFIELD AND PRUETT
CONSULTING PETROLEUM ENGINEERS
Wilson Tower
CORPUS CHRISTI, TEXAS
John W. Crutchfield — *Horton T. Pruett*

DENTON-SPENCER COMPANY, LTD.
CONSULTING PETROLEUM ENGINEERS
Barron Building — Calgary, Alberta

EARLOUGHER ENGINEERING
Petroleum Consultants - Core Analyses
Specializing in Secondary Recovery
Investigations - Appraisals - Operations
311-319 East Fourth Street
TULSA 3, OKLAHOMA
Office 2-5129 — Laboratory 2-6139

FITTING & JONES
Engineering and Geological Consultants
Petroleum — Natural Gas
Box 1637
223 S. Big Spring St. — Midland, Texas

MICHEL T. HALBOUTY
CONSULTING GEOLOGIST
AND PETROLEUM ENGINEER
Shell Building
Houston 2, Texas — Phone PR-6376

RICHARD V. HUGHES
Secondary Recovery of Oil
Mining Building — Stanford University
Stanford, California

PETROLEUM CONSULTANTS
Engineering and Geology
E. O. Bennett — James O. Lewis
D. G. Hawthorn — William Hurst
M. D. Hodges
1552 Esperson Bldg. — Houston, Texas

KELLER & PETERSON
Petroleum Consultants
Reserve Estimates — Property Appraisals
Petroleum and Geological Engineering
Reservoir Analysis
MIDLAND, TEXAS
P. O. Box 1787 — Phone 4-6181
W. O. Keller — L. F. Peterson

JAMES A. LEWIS ENGINEERING, INC.
Petroleum Reservoir Analysts
Core Analysis, Relative Permeability,
Restored State, Resistivity, Flood Tests
Comprehensive Reservoir Studies
Pressure Maintenance, Secondary Recovery
6923 Snider Plaza — P. O. Box 237
Dallas 5, Texas — Evansville 8, Ind.

W. T. MENDELL
Engineering & Geological Consultant
Second National Bank Building — Houston, Texas
CApital 7612

CLEVELAND O. MOSS
CONSULTING PETROLEUM ENGINEER
Estimates of Oil and Gas Reserves
Valuation — Production Problems — Proration
208 MIDCO BLDG. — TULSA 3, OKLA.

OILFIELD SERVICE COMPANY
Electric Logs — Gamma Ray — Caliper
Water Input Profiles
Specializing in Secondary Recovery
CHANUTE, KANSAS

ERNEST K. PARKS
CONSULTING PETROLEUM ENGINEER
Planning, Direction and Examination of
Oilfield Operations, Estimates of Oil and
Gas Reserves, Oil Property Valuation
614 S. HOPE STREET, LOS ANGELES 17, CALIF.
Telephone: VanDyke 4659

HARRY H. POWER
PETROLEUM AND VALUATION ENGINEER
Box 1542 — University Station
Austin, Texas

E. E. REHN
Consulting Petroleum Geologist
Oil Exploration
Wood Building, 624 Locust Street
EVANSVILLE, INDIANA

FRED E. SIMMONS, JR.
Geology and Petroleum Engineering
Louisiana Gulf Coast
Raymond 9408 — 807 Hibernia Bank Bldg.
New Orleans, Lousiana

SOL SMITH
CONSULTING ENGINEER
PETROLEUM AND NATURAL GAS
Reserves — Deliverability
Oil and Gas Proration
913 BROWN BUILDING
AUSTIN, TEXAS — PHONE: 89498

WM. H. SPICE, JR.
Consulting Geologist
2101-03 Alamo National Building
SAN ANTONIO 5, TEXAS

R. W. TESCH
PETROLEUM CONSULTANT
Valuation — Development — Management
Electric Bldg. — Fort Worth, Tex.

TRAFFORD & ASSOCIATES
Geological, Petroleum Engineering and
Management Consultants
E. Trafford, R. Pat, P. Klavi
Wales Hotel Bldg., 10th Floor, Calgary, Alberta
Phones 61212, 61224, 63132

HAROLD VANCE
CONSULTING PETROLEUM ENGINEER
Pet. Engr. Dept. — A & M College
College Station, Texas

Observations on Permeability Profiles

Reported by W. F. West

North Texas Section

Approximately one hundred members and guests of the North Texas Section attended a meeting at the Dallas Engineers' Club to hear H. H. Kaveler of the Phillips Petroleum Co., Bartlesville, Okla., discuss "Observations from Profile Logs of Water Injection Wells."

Kaveler reviewed certain concepts that are at present thought to be closely related to the horizontal permeability profiles of sand wells as determined by routine core analyses of the producing section. These concepts, in most cases, are concerned with controlling production from the well bore in such a manner as to eliminate "bypassing" or "trapping" of oil within the reservoir. They have resulted in the development of numerous practices such as selective perforating, selective shooting, acidizing and plugging, and regulation of flow rates to prevent irregular water or gas encroachment. In addition, the horizontal permeability profile is frequently the basis for the selection of injection patterns in secondary recovery projects.

The significance of the permeability profile is completely dependent upon the representative nature of the cores obtained. In most sandstones, which are heterogeneous systems, the permeability and porosity vary due to variation in the physical structure of the rock, and this variation is present both parallel and perpendicular to the bedding planes.

The horizontal permeability profile is utilized most frequently by petroleum technologists, probably because permeability measurements parallel to the bedding plane are usually greater than vertical permeability measurements, which usually leads to the notion that mass fluid movements in a reservoir are predominantly in a horizontal direction.

Kaveler observed that the heterogeneity of the horizontal permeability profile makes it very unlikely that a truly representative profile that will correlate between wells can ever be obtained in a typical sandstone reservoir. This variation in horizontal permeability can be visualized as a series of resistances to horizontal fluid movements which make it extremely unlikely that the most permeable sections as determined by core analyses are actually those through which the greatest volumes of fluid will flow.

The vertical permeability also influences the path of fluids through rock, and has an effect in establishing flow capacities different from those expected from the horizontal permeability profiles obtained by core analyses. The area through which vertical flow may occur in a reservoir increases as the square of the radius outward from the producing well. Thus, a substantial part of the fluid passing the sand face in the well bore could move through vertical paths even though the permeability in that direction is relatively low. As a consequence, flow through the bulk of the reservoir rock must follow meandering three dimensional paths that are defined by the "composite" permeability arising from the existing values of the horizontal and vertical components from point to point. The influence of vertical permeability would be to remove the horizontal permeability as the sole criterion of flow at the face of the sand. For that reason, the flow at the sand face should not necessarily be correlative with the horizontal permeability profile.

In order to clarify the above theoretical discussion, Kaveler presented data obtained from coring nine wells in the center of ten-acre locations for the purpose of providing water injection wells in the Bartlesville (Burbank) Sand of the North Burbank Field in Osage County, Okla.

In addition to routine core analyses, water injection rate profiles were obtained on these wells utilizing a recently developed highly reliable flow profile device. Careful control was maintained on the injected water so plugging action arising from suspended solids could not account for any of the intake characteristics obtained.

H. H. KAVELER

A comparison of the permeability profiles and the injection rate profiles revealed that generally the water was entering the reservoir rock at points that were not correlative with the measured horizontal permeability of the sandstone. In addition, the water injection profiles were found to vary significantly over a one-year period of time.

The lack of correlation between permeability and flow at the sand face of wells in this typical sandstone is likely to be found in all other reservoir rocks with the possible exception of those containing extensive fracturing or cavernous characteristics. The change in injection rate profiles with time further indicates that changes within the body of rock are occurring so that the measured permeability or water injection rate profile of any particular well does not reflect even approximately the flow through the entire reservoir.

Kaveler's principal conclusion from the data obtained to date is that most of the practices employing the principle of "selective" control of the flow of fluids at the face of the sand in a well need to be re-examined, because most of these practices are tailored after the horizontal permeability profile, which it now appears does not measure relatively the flow at the sand face of a productive section. ★ ★ ★

Officers of the North Texas Section for 1952 are as follows:

R. G. Parker, Chairman

Kenneth F. Anderson, Vice-chairman (Dallas)

Henry J. Gruy, Vice-chairman (Fort Worth)

Buck Joe Miller, Vice-chairman (Wichita Falls)

M. I. Taylor, Secretary-treasurer

Directors are Paul M. Wiley, Marshall L. Stirling, Richard T. Bright, Everett G. Trostel and Rollie P. Dobyns.

Sites of the Petroleum Branch, AIME, Fall Meetings are the new Statler Hotel in Los Angeles (left) and the Rice Hotel in Houston, seen in the upper right hand corner of the aerial picture of downtown Houston at the right.

Fall Meetings Set for Houston and Los Angeles

The site of the 1952 Mid-Continent Fall Meeting of the Petroleum Branch, AIME, to be held Oct. 1, 2 and 3, is the Rice Hotel in Houston, Tex. The West Coast Fall Meeting this year will be conducted in the new (not yet completed) Statler Hotel in Los Angeles, Calif.

Some 1,200 AIME members are expected to attend the Houston meeting and an additional 300 are expected at the Los Angeles meeting Oct. 23 and 24. In Houston, the Rice Hotel will serve as headquarters for the Mid-Continent gathering. All technical sessions, committee meetings and social functions are tentatively scheduled to be held in the Rice.

In addition to the Rice Hotel, the Texas State and Lamar hotels will be available for room reservations for members attending the meeting. The latter two hotels are within four blocks of the Rice and the technical sessions. A preliminary outline of the meeting, subject to change, follows:

Tuesday evening, Sept. 30 — advance registration.

Wednesday a.m., Oct. 1 — two technical sessions.

Wednesday noon, Oct. 1 — welcoming luncheon.

Wednesday p.m., Oct. 1 — open meeting of Branch Executive Committee.

Wednesday evening, Oct. 1 — entertainment function.

Thursday a.m., Oct. 2 — two technical sessions.

Thursday p.m., Oct. 2 — economic session.

Thursday evening, Oct. 2 — Petroleum Branch Annual Banquet.

Friday a.m., Oct. 3 — two technical sessions.

Friday p.m., Oct. 3 — one technical session.

Some 35 technical and economic papars will be presented at the Houston meeting and are now being written by authors in the field and laboratories under the guidance of the Branch Technology Committee. Officers of that committee, which is charged with gathering papers for the fall meeting, are Douglas Ragland, chairman, Humble Oil and Refining Co.; Jack H. Abernathy, vice-chairman for drilling, Big Chief Drilling Co.; E. P. Hayes, vice-chairman for production, The Texas Co.; W. H. Justice, vice-chairman for gas, the La Gloria Corp.; and Milton E. Loy, vice-chairman for California, Schlumberger Well Surveying Corp.

Within the next few weeks, each Petroleum Branch member will receive a postal card on which he may make reservations at the Rice, Texas State and Lamar hotels in Houston. The cards will be stamped and self-addressed for easy use. Please fill out the card and post it as soon as it is received in order that reservations may be assured. Past experience has proven that the majority of members obtain their reservations in this manner early in the year. Make it easy on yourself by returning the postal card promptly.

An additional 10 to 12 papers will be presented at the West Coast Fall Meeting in Los Angeles. The meeting will be switched this year from its previous place in the Elk's Club to the new Statler Hotel in Downtown Los Angeles. Schedule of events follows:

Thursday a.m., Oct. 23 — technical session.

Thursday noon, Oct. 23 — Petroleum Chapter luncheon.

Thursday p.m., Oct. 23 — technical session.

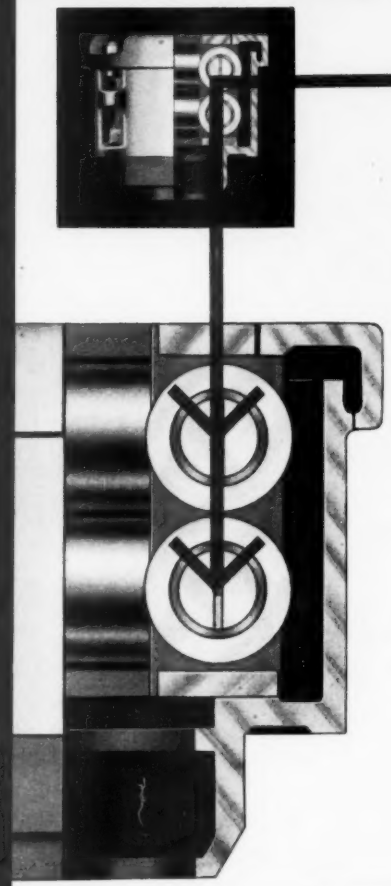
Friday a.m., Oct. 24 — technical session.

Friday noon, Oct. 24 — Southern California Section luncheon.

Friday p.m., Oct. 24 — technical session.

Friday evening, Oct. 24 — dinner dance.

★ ★ ★



this is why Baash-Ross ROLLER KELLY BUSHINGS are *Unsurpassed*

for smooth feed . . . long kelly life . . . steady rotation!

No drilling operation is completely modern without a Baash-Ross Roller Kelly Bushing—because this is the *only* Bushing that combines the friction-free sensitivity of roller bearing operation with the engineering advantages of TWO *large-diameter rollers* bearing against each kelly face!

Why TWO Rollers— no more—no less

One roller permits wobble!

1. Because at least *two* rollers against each face are necessary to give stability to the kelly as it rotates (preventing gyration and wobble) . . . and to give adequate "non-corrugating" driving surface against each kelly face.

Two rollers give stability!

2. But more than two limits the size of each roller . . . necessitates smaller bearing areas and pin diameters . . . multiplies service and maintenance problems.

These engineering features are important, too . . .

In addition to the big advantage of having *two* rollers against each kelly face, these additional Baash-Ross features are also vitally important . . .

- **BRONZE BUSHINGS** between rollers and pins prevent steel-to-steel contact, resist galling under high torque loads, assure free rotation and quick response to the most delicate bit feed!
- **REVERSIBLE PINS** can easily be rotated to bring unworn back side of pins to front for additional service after front sides (where driving pressures are concentrated) become worn. Cuts maintenance costs to a minimum!
- **INDIVIDUAL GREASE DUCTS,** centralized where they're easy to reach, assure proper lubrication to each separate roller and pin!
- **SOLID ONE-PIECE COVER** is unusually strong and rigid, yet easily removed when desired. Its streamlined surface has no projections to catch in lines or clothing—a vital safety advantage!
- **ROLLER ASSEMBLIES** can be quickly interchanged to adapt a single body to various kelly sizes. For example, one Baash-Ross Bushing fits *all* square kellys from 3" to 6" by simply changing the roller assemblies. Or the same Hex Bushing fits all hex kellys from 3½" to 7" by changing only the roller assemblies. Simple, quick—cuts bushing costs to the bone!

Baash-Ross Roller Kelly Bushings are available in sizes to fit all popular kellys . . . 2½" to 6" in square kellys, 3" to 7" in hex kellys.

For complete details, see your nearest Baash-Ross representative—or write direct.

A 6-way saving in Drilling Costs!

Wherever Baash-Ross Roller Kelly Bushings are used, operators are enthusiastic over the multiple savings these modern bushings make possible. By eliminating the erratic bit control and sudden "feed-offs" inherent in conventional kelly bushings, Baash-Ross *Roller* Kelly Bushings keep the bit digging at a uniform rate, assuring . . .

1. **More footage per bit!**
2. **Faster drilling speeds!**
3. **Longer kelly and drill string life!**
4. **Longer rotary equipment life!**
5. **Reduced risk of twist-offs!**
6. **More accurate weight indication!**

FOR AUTOMATICALLY CENTERING

the Kelly Bushing into the rotary table, a Baash-Ross Kelly Bushing Guide Skirt is available. Fits all Baash-Ross "2RC" Roller Kelly Bushings . . . others on special order. Write for complete details!

Baash-Ross Roller Kelly Bushings are sold through leading supply stores!

Baash-Ross TOOL COMPANY

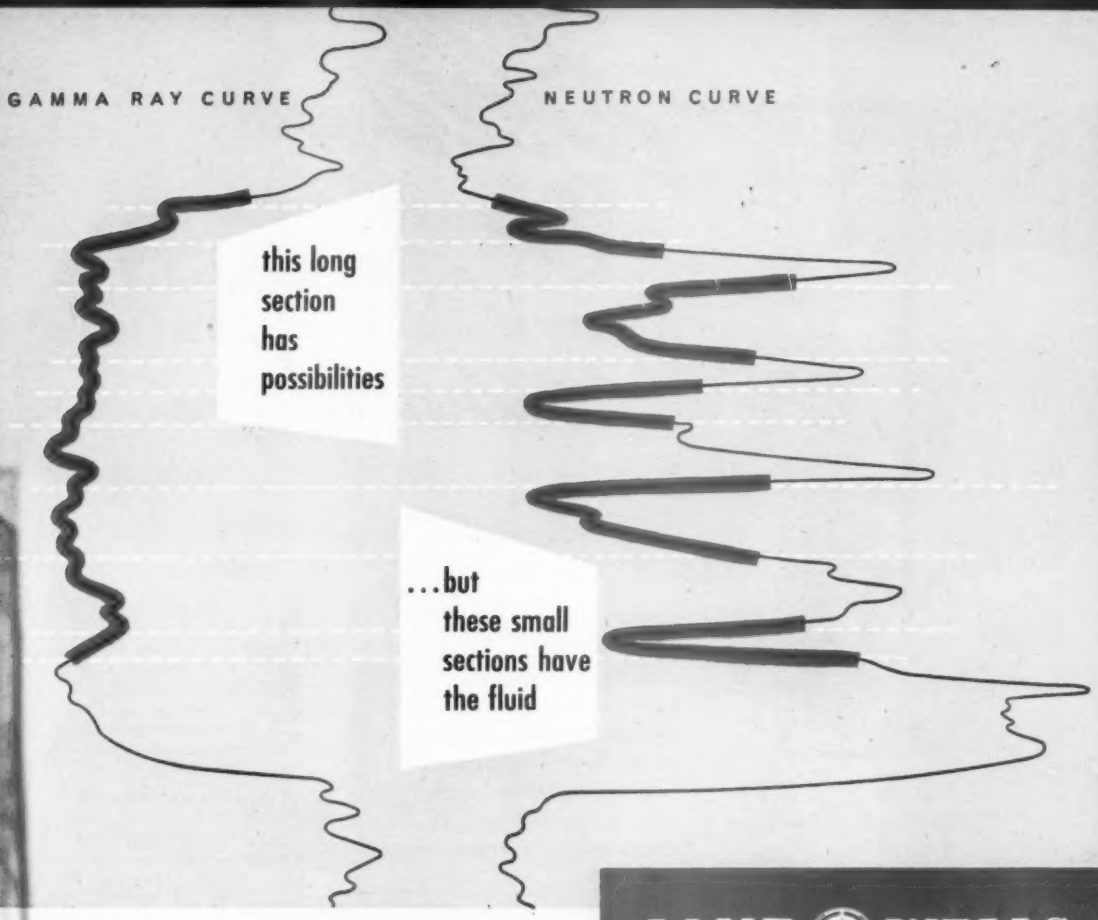
BAASH ROSS

Our 32nd year

GENERAL OFFICES: 5512 SO. BOYLE AVE., LOS ANGELES 58

OKLAHOMA CITY 9 • HOUSTON 1 • ODESSA • CASPER

Export Offices: 11 W. 42nd St., New York 18



You get the full story with the two curves of

LANE WELLS
Radioactivity
WELL LOGGING

Gamma Ray does a great job in locating possible production, but when you add the neutron curve, "possible" is apt to change to "probable"—or, in a known formation, to "positive production." Add the casing collar log, run at the same time, and you have the full story of your well, pinned down by immovable bench marks, to guide you in making the most profitable completion. In either cased or open hole, Lane-Wells Radioactivity Well Logging provides the most complete down-hole information possible.

Ask Your Lane-Wells Man!

Tomorrow's Tools—Today!

AR 901

General Offices, Export Office and Plant • 5610 So. Soto St. • Los Angeles 58, Calif.

LOS ANGELES • HOUSTON • OKLAHOMA CITY • LANE-WELLS CANADIAN CO. IN CANADA • PETRO-TECH SERVICE CO. IN VENEZUELA

DISCUSSION OF THIS AND ALL FOLLOWING TECHNICAL PAPERS IS INVITED
Discussion in writing (3 copies) may be sent to the Editor, *Journal of Petroleum Technology*, 408 Trinity Universal Bldg., Dallas 1, Texas, and will be considered for publication in the Transactions volume *Petroleum Development and Technology*. Discussion will close December 31, 1952. Any discussion offered thereafter should be in the form of a new paper.

A SIMPLIFIED METHOD FOR COMPUTING OIL RECOVERY BY GAS OR WATER DRIVE

HENRY J. WELGE, THE CARTER OIL CO., TULSA, OKLA., MEMBER AIME

ABSTRACT

The approximate methods which are now in use for calculating oil displacement from reservoirs by gas-cycling or gravity-drainage at constant gas pressure, or by water flooding, make use of fundamental relationships derived by Leverett[1] and Buckley and Leverett.[2] The mathematical equations needed are derived by applying Darcy's law to the flowing phases, and by material balance considerations. In general, any treatment of this type gives, for any particular exploitation time considered, a plot of oil saturation against distance in the reservoir. The oil recovery must then be obtained by integrating in some manner the area under the plot.

A useful analytical method has been derived for computing the average saturation, and hence the oil recovery. Use of this method simplifies the calculations because it makes unnecessary any numerical integrations, and even the saturation distribution plots are not needed. A further advantage of the method is that knowledge of the relative permeabilities is required only for a limited and intermediate saturation range.

In both the Buckley and Leverett method and the method discussed here, a linear sand section is assumed, and in the case of gas drive the gas pressure is assumed sufficiently constant both with respect to reservoir position and time so that changes in gas density, solubility, or reservoir volume factor are negligible. Thus, the exploitation contemplates oil displacement as by an immiscible phase. Examples are given to illustrate how the new method can be used.

[1]References given at end of paper.

Manuscript received in the office of the Petroleum Branch Sept. 25, 1951. Paper presented at the Petroleum Branch Fall Meeting in Oklahoma City, Okla., Oct. 3-5, 1951.

INTRODUCTION AND THEORETICAL BACKGROUND

This paper treats a simplified method for computing oil recovery when the oil is displaced from the reservoir sand by a fluid which, within the limits of accuracy desired, can be assumed to be incompressible and immiscible with the oil. The method makes use of two basic relations originally developed for the case of water displacing oil. However, the case of gas displacing oil saturated with gas at a constant (or nearly constant) pressure may also be considered a displacement by an immiscible fluid. This is possible for the reason that the concentration of the gas in the oil never changes if the pressure is fixed. Consequently, any additional free gas must remain undissolved in the oil, and so must act essentially as an immiscible phase. For convenience, the case of gas drive will be considered first.

Both of the two basic relations needed refer to a linear reservoir, or one which may be somewhat idealized so that a constant cross-section is exposed to fluid flow. Further, the displacing phase is injected at one end, or face, of the reservoir, while the produced fluids are understood to emerge at one point only, which is the opposite face of the reservoir. As indicated in Fig. 1, the reservoir may be inclined by some angle θ.

The first of the required equations may be derived by applying Darcy's law to both displacing and displaced phases, and subtracting the two equations. The result for water drive has been given previously, as Equation (13) of the reference by

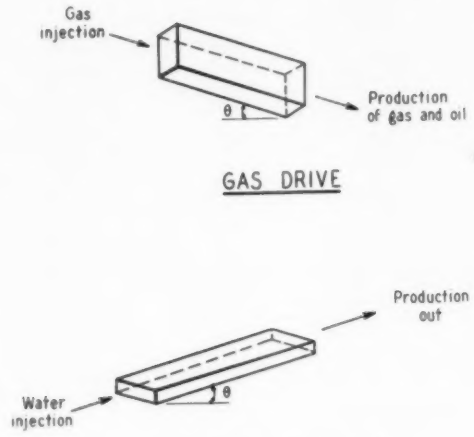


FIG. 1

Leverett[1] cited above. The result for the case of gas drive, derived in completely analogous manner, may be written:

$$f = \frac{c}{c+h} - \frac{K \triangle D_g \sin\theta}{\mu_o v_o} \frac{k_{o11}}{c+h} \quad . \quad . \quad . \quad . \quad . \quad (1)^*$$

The term comprising the capillary pressure gradient has been dropped from Equation (1). This procedure is usual practice in reservoir calculations, and justification will be given later in this paper. Equation (1) may equally well be expressed in terms of f_{o11} which is $1-f$ to give:

$$f_{o11} = \frac{h}{c+h} + H \frac{k_{o11}}{c+h} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a)$$

The second basic relation required appears as Equation (1) on page 109 of the reference by Buckley and Leverett[2] cited above. It expresses a material balance over a thin section of the reservoir. In terms of gas drive it may be written in the form:

$$v \frac{\partial f}{\partial x} + \frac{\partial S}{\partial t} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Since f by Equation (1) is a function of S only (through k_{o11} and h), we may write for the first derivative in Equation (2),

$$\frac{\partial f}{\partial x} = \frac{df}{dS} \cdot \frac{\partial S}{\partial x} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which the total derivative df/dS is obtainable from Equation (1). After substituting (3) into (2), Equation (2) can be rearranged and partially solved by standard methods to give the relation:

$$\left(\frac{\triangle x}{\triangle t}\right)_S = \left(\frac{dx}{dt}\right)_S = -\frac{\dfrac{\partial S}{\partial t}}{\dfrac{\partial S}{\partial x}} = v\frac{df}{\partial S} = vf' \quad . \quad . \quad (4)$$

*A complete table of nomenclature is given at the end of this paper.

The value of df/dS, hereinafter denoted by f', for any given saturation, S, must be obtained by plotting f as calculated from Equation (1) and taking slopes from the plot (see Fig. 2).

Equation (4) gives the distance traveled by the various gas saturations in any given time, $\triangle t$. The distance traveled, $\triangle x$, is proportional to the f' function, the constant of proportionality being $v\triangle t$. Thus, a plot of S against f', such as the one in Fig. 2, gives also the gas saturation as a function of distance. It is necessary only to multiply the f' scale by the value of $v\triangle t$ corresponding to the time at which the saturation distribution is desired. Thus the curve describing saturation as a function of position in a core or reservoir at any time during the exploitation remains always similar except for horizontal "stretching," or multiplying of all abscissae by a constant factor.

In a system which is being held at constant pressure the oil recovery can be directly related to the change in volume of free gas, *i.e.*, to the average gas saturation. In general, in order to find the average gas saturation from any plot of S *vs* x, it has in the past been necessary to integrate in some manner the area under the plot. The operation of plotting and integrating must be performed as often as recovery evaluations are desired. It is well realized by anyone who has had to carry through the entire process of evaluation that it is a tedious and time-consuming job.

In the event the velocity of the front of farthest gas penetration and the gas saturation at break-through are desired, the f' curve must be cut off as indicated in Fig. 2, in such a manner that the areas lying beneath and to the left of the original and the amended curves are equal in accordance with the suggestion made by Buckley and Leverett.[2] This construction was recently shown to be mathematically valid by von Neumann* and, somewhat later, by Brinkman.[3] It is equivalent to making equal in size the two areas shown shaded in Fig. 2.

*Private consultation. John von Neumann also orginated the more convenient method for determining the point at which the f' curve must be cut off that is presented in the next paragraphs.

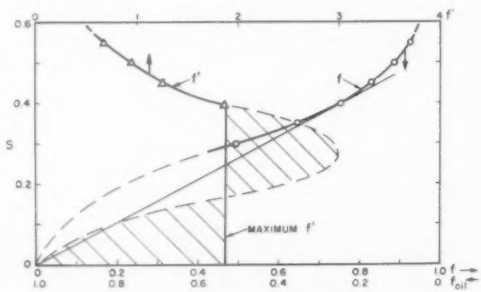


FIG. 2 — FLOWING GAS FRACTION IN TERMS OF GAS SATURATION, MILE SIX POOL, PERU.

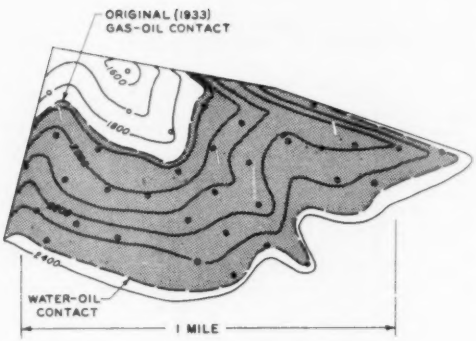


FIG. 3 — MILE SIX POOL, PERU.

The cut-off construction applied to the f' curve is analytically equivalent to the use of an average f' value covering the gas saturation range from zero to the cut-off gas saturation. It will be noted further that the required average value of f' (see Fig. 2) is the slope of a line drawn through the origin and tangent to the originally constructed f curve. This is true because of the requirement, developed in analytic geometry, that the slope of a secant intersecting a curve in two points is the average slope of the curve. Since the tangent intersects the f curve at the origin and at the point of tangency, it fulfills the above requirement.

The slope, then (with reference to the S axis), of the tangent shown in Fig. 2 represents the maximum value of f', or f'_{max}. This maximum slope corresponds to the highest velocity with which any gas saturation moves, and therefore can be used in conjunction with Equation (4) to obtain the time of gas break-through at the producing wells.

The construction of a tangent line like that shown in Fig. 2 indicates the lower limit of saturation below which the plot of the f curve is not required; hence relative permeability information is also unnecessary below this saturation. In particular, it should be noted that knowledge of the so-called equilibrium gas saturation, or lowest gas saturation at which gas can flow, is not required in this method of evaluating performance by gas drive. Relative permeabilities are difficult to measure in the region of low gas saturation, and considerable experimental time can be saved if they are not needed. It will be shown later that relative permeabilities are likewise usually not needed in the region of very high gas saturations. The regions in which the f function is not required are shown by dashed lines in Fig. 2; they are inserted there only for the purpose of illustrating the foregoing discussion.

The error resulting from dropping the term containing the capillary pressure gradient in arriving at Equation (1) may now be briefly discussed. As described above, the S *vs* f' curve in Fig. 2 will give the saturation distribution with respect to distance along a rock sample or a reservoir at any instant during the progress of the exploitation. Consider the instant at which gas is first produced; the abscissal position f'_{max} will then represent the outflow point of the rock system receiving flow, or the field position of the producing wells. As the length of the system considered increases, the distance corresponding to the abscissa length from zero to f'_{max} increases. That is, a distance scale laid off along the f' axis must be compressed more and more. When this is done, the saturation gradient or slope of the S *vs* x curve proportionately decreases as the system length encompassed in the distance from zero to f'_{max} increases. The capillary pressure depends solely on the saturation,[1] so the capillary pressure gradient also will become of smaller importance as longer systems are considered. Test calculations have been made in which the capillary term was retained in Equation (1) for the purpose of comparing its magnitude with the size of the other terms. These calculations showed that the term frequently could not be dropped if the systems were only a few inches long, as in the case of cores intended for core analysis; but that it became negligible in systems having the dimensions of reservoirs.

A similar line of reasoning may be applied to any later stage in the gas drive after the instant of gas break-through. In this case the saturation and capillary pressure gradients will be smaller still than they were before, and hence of still less consequence.

DERIVATION OF PROPOSED METHOD OF CALCULATION

Consider the nature of the f function at a point near the inlet to the linear sand body. If the first section or slice, δx thick, of the sand body is very thin compared to the maximum distance penetrated by the injected gas front, it is evident that the slice has experienced a great many of its pore volumes of gas throughput. Accordingly, the flow of oil must have all but ceased in the slice, which means that $f = 1$ and $f' = 0$ at $x = 0$.

A further convenient relationship may be derived from Equation (4) by applying it to the situation near the outlet face of the linear sand body, where $x = L$, the reservoir length. Here

$$\frac{1}{f'} = \frac{1}{f'(S)} = \frac{v\triangle t}{L} = Q_i,$$

where Q_i is the cumulative injection in pore volumes at the time the saturation, S, reaches the outflow face.

With the aid of the considerations noted in the preceding paragraphs, the desired average gas saturation in the sand, S_{av}, can be evaluated:

$$S_{av} = \frac{\int_1^2 S dx}{x_2} \quad \ldots\ldots\ldots\ldots \quad (5)$$

where the limits 1 and 2 refer to the inlet and outlet of the sand. Equation (4) shows that the distance, x, attained in the sand by a given saturation is proportional to the f' function; consequently this function may be used instead of x in the numerator and denominator of Equation (5) for the purpose of averaging:

$$S_{av} = \frac{\int_1^2 S df'}{f'_2} \quad \ldots\ldots\ldots\ldots \quad (6)$$

since f' denotes df/dS, it is possible to integrate Equation (6) by parts.

$$S_{av} = \frac{S_2 f_2 - \int_1^2 f\,dS}{f_2} = S_2 - \frac{\int_1^2 df}{f_2} = S_2 - \frac{f_2 - 1}{f_2'}$$

or $$S_{av} - S_2 = (f_{s1})_2\, Q_1 \quad \ldots\ldots\ldots \quad (7)$$

Equation (7) readily gives the difference between the average and terminal gas saturation, so that only one saturation, the one near the outlet of the sand, need be evaluated for the purpose of calculating oil recovery by gas cycling or gas cap drive at constant gas pressure.

It should be particularly noted that the product $(f_{s1})_2\, Q_1$ always gives the saturation increment between the average gas saturation and the terminal gas saturation obtaining near the outflow face of the sand. Evaluation of this product for any stage in the exploitation whatever readily permits calculation of S_{av}, which is the total fractional recovery of oil from the reservoir.

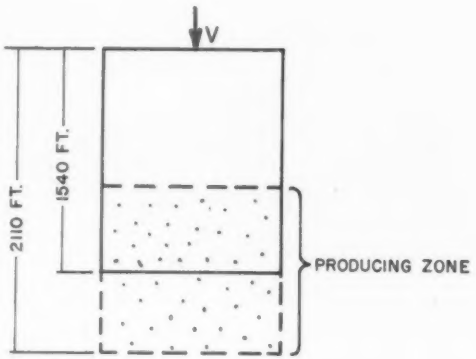


FIG. 5 — IDEALIZED REPRESENTATION, MILE SIX POOL, PERU.

ILLUSTRATIVE EXAMPLE

To illustrate the use of the average gas saturation, recovery calculations made for the Mile Six Pool in Peru[4] were selected, because the results of the calculations can be compared directly with the actual known behavior of this pool over most of its producing life. A contour map of this field is shown in Fig. 3. The average dip is 17.5°, the average permeability was taken to be 300 md, and the average hydrocarbon occupied porosity* was 0.1625. The viscosity of the reservoir oil and gas were estimated to be 1.32 and 0.0134 cp, respectively, and their densities were taken at 0.78 and 0.08 g/cu cm, respectively.

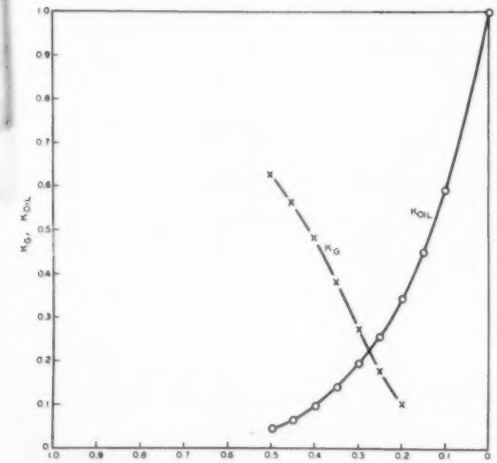


FIG. 4 — RELATIVE PERMEABILITIES AS FUNCTIONS OF GAS SATURATION EXPRESSED AS A FRACTION OF HYDROCARBON-OCCUPIED PORE SPACE.

The relative permeability functions used are shown in Fig. 4. It should be remembered that the relative permeabilities as measured on laboratory core samples should be corrected for the effects of stratification before being used in field calculations. This factor was considered in arriving at the curves given in Fig. 4. An alternate procedure that can be used whenever adequate core analysis information is available is to make separate reservoir behavior calculations for each layer.

Since the calculation of reservoir behavior can be applied only to flow in one direction, as illustrated in Fig. 1, some geometric adjustment is needed to produce even an approximate answer in a problem of this type. Essentially the actual irregularly shaped field is replaced by an assumed parallelepiped in which the dimensions are chosen to give the closest representation possible. The plan view of the idealized field is shown in Fig. 5. The overall length of 2,110 ft shown is obtained from Fig. 3 and is the estimated average distance (parallel to the formation) from the original gas-oil contact to the oil-water contact. The length of 1,540 ft, also scaled from Fig. 3, represents the distance along the dip from the original gas-oil contact to the average withdrawal point. The latter point or level is taken midway between the producing wells so that as many wells lie upstructure from it as downstructure. The distance of 1,540 ft will be taken as the average length of the idealized linear reservoir.

The average fluid velocity in the hydrocarbon-occupied pore space v is obtained in the following manner. The average cross-section exposed to flow may first be obtained by dividing the volume of original reservoir oil-in-place, 55×10^6 bbl or 309×10^6 cu ft, by 1,540 ft; the result is 201,000 sq ft. The average withdrawal rate, in terms of reservoir volume, of oil and free gas during the interval 1933-1946 was 23.5×10^6 cu ft

*Total porosity multiplied by the factor, (1 - fraction of connate water).

per year. Division of this withdrawal rate by the average cross-sectional area yields a pore velocity v of 116.8 ft per year (1.13×10^{-4} cm/sec).

In Table I are shown the calculations carried out in accordance with the relations developed above. It will be observed that the terminal gas saturation is treated as the independent variable in constructing the table. Next the function h is evaluated for each saturation chosen, and entered in column (2). This function is then used in calculating the values appearing in columns (3) and (5), the sum of which gives the value for f_{o11} which appears in column (6). The quantity f_{o11} is plotted against S as in Fig. 6, which is a copy of Fig. 2 from which the portion of the construction has been deleted that is not needed in the usual reservoir evaluation. The slope of the f (or f_{o11}) curve in Fig. 6 (with reference to the S axis) is measured with a straight edge for each value of S taken originally, and entered in column (7).

It will be observed in Table I that the oil recoveries are in reasonable agreement with the field data. The differences observed are in part due to the fact that the exploitation velocities were somewhat lower than the average assumed in the calculations for the first eight years of the gas injection program, and somewhat higher for the next four years. The calculated gas/oil ratios differ more widely from the field data. It has been observed, in general, that the flowing gas/oil ratio is a more sensitive function of the assumed conditions, such as gas velocity, permeability, or geometical complexities, than is the oil recovery. It may be of interest to mention that the calculation time for the above example was about a man-day; this time is contrasted with an estimated man-week if the conventional integration technique is used.

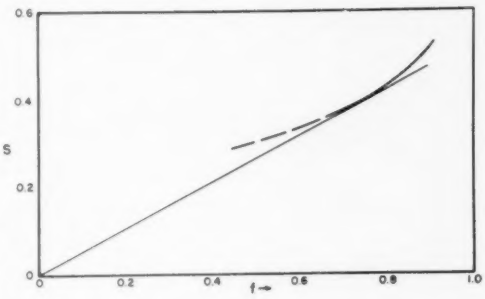


FIG. 6 — FLOWING GAS FRACTION IN TERMS OF GAS SATURATION, MILE SIX POOL, PERU.

It is unnecessary to plot a curve showing the saturation distribution with distance in the reservoir (such as the f' *vs* S curve), since the average gas saturation suffices to determine

Table I — Typical Calculations of Gas Cap Drive Performance

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
									Fraction of Oil in Place Recovered (Cumulative)		Flowing GOR (cu ft/bbl)	
Gas Saturation Near Outlet S_2	$\frac{h = k_{o11}}{k_g}$ (Fig. 4)	$\frac{h}{c+h}$	k_{o11} (Fig. 4)	$\frac{Hk_{o11}}{c+h}$	$(f_{o11})_2 =$ (3) + (5)	$\left(\frac{df}{dS}\right)_2 = \frac{1}{Q_1}$	$\frac{t = \frac{1{,}540 \text{ ft}}{116.8 \text{ ft/yr}} S_{av} - S_2}{\times Q_1} = f_{o11} Q_1$ = (6) ÷ (7)	$S_{av} =$ (1) + (9)	Actual Field Data	$\frac{f}{f_{o11}}$ x 88.6 x 5.61 + 400	Actual Field Data
0.30	0.715	0.00725	0.197	0.497	0.504							
0.35	0.364	0.0037	0.140	0.354	0.358							
0.395*	0.210	0.00214	0.102	0.2585	0.261	1.875	7.05	0.139	0.534	0.535	1,800	800
0.40	0.200	0.00204	0.097	0.243	0.245	1.81	7.1	0.135	0.535	0.543	1,930	700
0.45	0.118	0.00120	0.0667	0.169	0.170	1.25	10.6	0.136	0.586	0.614	2,820	2,300
0.50	0.0715	0.00073	0.045	0.114	0.115	0.94	14.1	0.122	0.622	0.675	4,220	2,100

Dimensionless ratios required:

$$c = \frac{\mu_{o11}}{\mu_g} = 98$$

$$H = \frac{K \Delta D g \sin \theta}{\mu_g v_o} = 248.5^{**}$$

Reservoir oil volume factor = 1.25

Super compressibility factor for reservoir gas (Z factor) = 0.74

$$\frac{\text{Volume Surface Gas Per Volume Stock Tank Oil}}{\text{Volume Reservoir Gas Per Volume Reservoir Oil}} = \frac{850 \text{ psi}}{14.7 \text{ psi}} \times 1.25 \times \frac{(60°\text{F} + 460)}{(114°\text{F} + 460)} \times \frac{1}{0.74} = 88.6$$

*Oil "bank", or shock front, occurs at this saturation (see Fig. 2). For all earlier stages in the gas injection program, $S_2 = 0$, and oil recovery $= S_{av} = Q_1$. The values shown for f and f_{o11} (column (6) above) for saturations less than the "bank" saturation of 0.395 are not required after the position of the bank is determined, and they should not be used further.

**c.g.s. units will be found convenient for expressing the non-dimensional number H. The c.g.s. unit for permeability is sq cm; darcies x .987 x 10^{-8} = permeability expressed in cu cm. $V_o = V\pi = 1.13 \times 10^{-4}$ cm/sec x 0.1625 = 0.184×10^{-4} cm/sec.

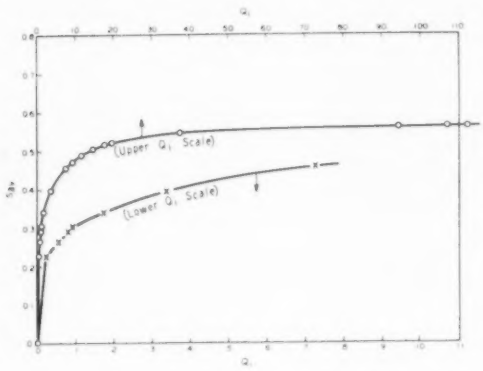


FIG. 7 — RESULTS OF A GAS DRIVE EXPERIMENT ON A CORE OF BARTLESVILLE SANDSTONE.

the recovery, while the terminal saturation near the outflow face (the independent variable first assumed in column 1) fixes f, and hence the flowing gas/oil ratio at any desired time during the exploitation. It will also be noted that the maximum value of S for which relative permeabilities are needed is the value (column 1) corresponding to the greatest exploitation time (column 8) in which one is interested.

It is realized that the geometric and other approximations required in the illustrative example used are more severe than they would be in many other cases. Frequently the field geometry and the disposition of the wells are more amenable to simulation by a linear reservoir.

SUGGESTED TREATMENT FOR THE CASE INVOLVING AN INITIAL PERIOD OF DECLINING PRESSURE

Frequently a field has been exploited by dissolved gas drive for a time before a gas injection and pressure maintenance program is begun. In this event the calculations are made as before, except that at the end of the computations the time scale must be aligned in relation to calendar time. This is done as follows: In general, the stock tank oil that has been recovered by primary depletion up to the start of the gas injection program will be known; this oil recovery should be expressed as a fraction of the original oil in place and subtracted from unity. The so obtained fraction representing the residual oil, if multiplied by the ratio of the later to the initial formation volume factors, gives the residual oil saturation at the start of gas injection. The complement of this number gives the average gas saturation at the start of injection. The time at which this particular saturation is reached, computed by the method shown in Table I, is then identified with the date of the start of gas injection.

The average gas saturation at later times will not, in this case, be equal to the fractional oil recovery as before. Instead, the latter must be calculated by a process which uses the formation volume factors in a precisely inverse manner to that described above.

A calculation made as outlined above for the case including a period of primary production with pressure decline will be subject to some error, for the reason that the distribution of gas in the reservoir arising from dissolved gas drive will not be identical with the distribution caused by gas injection at constant pressure. The accuracy to be expected from this type of calculation has, however, been tested for the case just discussed. The test consisted of a comparison between results obtained by the method described in this paper and by a much more comprehensive treatment in which most of the simplifying assumptions with regard to reservoir linearity, constancy of pressure, etc., were removed. The latter exhaustive computation gave a result for oil recovery after 30 years' gas cycling of 31.5 per cent; the former simple treatment, 29.8 per cent. The reasonably good agreement between these two figures suggests that the accuracy obtainable by the approximate method will be satisfactory for engineering purposes, particularly if gas throughputs in excess of about one pore volume are considered.

The work described in this paper represents part of a continuing program relating to mathematical and physical aids for carrying out pool studies and the associated reservoir engineering. The method of calculation described above has been used by a number of reservoir engineers in a semi-routine manner and has given results upon which economic evaluations have been based.

CALCULATION OF RELATIVE PERMEABILITY RATIO FROM LABORATORY GAS DRIVE DATA

The above relations are also useful when it is desired to make a calculation of relative permeability ratio from laboratory displacement data. The information required consists of (1) cumulative gas injection volumes at average core pressure and (2) the corresponding average gas saturations in the core. If the core is initially completely liquid-saturated, the average gas saturation at any time will be equal to the cumulative

Table II

$$c = \frac{\mu_{oil}}{\mu_{N_2}} = \frac{0.82}{0.018} = 45.6$$

(1)	(2)	(3)	(4)	(5)	(6)
S_{av}	Q_i	$f_{oil} = \frac{d\,S_{av}}{dQ_i}$ (Fig. 6)	$\frac{S_{av}-S_i}{f_{oil}\,Q_i} = \frac{S_o}{f_{oil}\,Q_i}$	(1)-(4)	$\frac{k_{ro}}{k_{roi}} = \frac{1-f_{oil}}{45.6\,f_{oil}}$
0.225	0.251	0.1127	0.028	0.197	0.1723
0.30	0.90	0.0525	0.047	0.253	0.396
0.35	2.02	0.038	0.077	0.273	0.555
0.40	3.63	0.025	0.091	0.309	0.855
0.45	7.2	0.0112	0.081	0.369	1.933
0.475	9.8	0.00778	0.076	0.399	2.79
0.50	13.8	0.0048	0.066	0.434	4.54
0.525	22	0.00214	0.047	0.478	10.22
0.55	55	0.000333	0.018	0.532	65.9
0.56	107	0		0.56	∞

liquid discharged, expressed in pore volumes. For purpose of illustration, a typical set of such data is shown plotted in Fig. 6. The data were obtained by displacing n-decane from a core of Bartlesville sandstone by nitrogen gas, using a pressure drop sufficiently high so that the end effect, or abnormal capillary retention of liquid near the downstream core face, was restricted to negligible importance in comparison with the total amount of liquid in the core.

A typical calculation of liquid-gas relative permeability ratio from the data in Fig. 7 and using the relations developed previously, is given in Table II. Here columns (1) and (2) represent the starting experimental data plotted in Fig. 7. The loss of oil with reference to total input (or outflow) will be equal to f_{o11} and is given by the slope of the curve in Fig. 7; it is entered in column (3). The k_o/k_{o11} ratio obtained is shown plotted in Fig. 8.

If independent information on one or the other relative permeability, k_o or k_{o11}, is available, the other may obviously be obtained from the ratio. For example, it has been previously shown[8] that k_{o11} may be estimated by computation from the nature of the capillary pressure *vs* saturation curve[8,9] obtained on a porous material. The separate relative permeabilities may thus be measured, if desired, through the use of two relatively inexpensive and routine laboratory procedures: (1) a simple gas-oil displacement experiment, and (2) a capillary pressure experiment.[9]

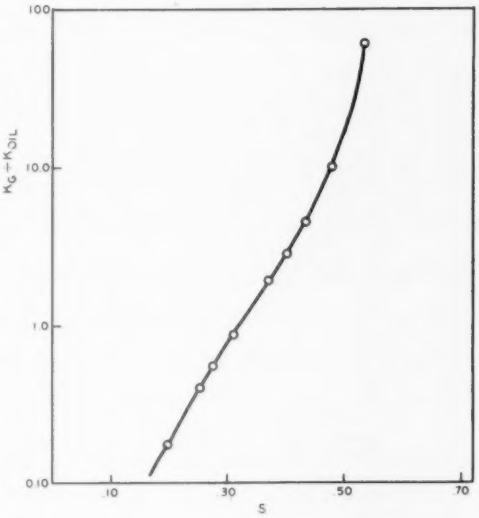


FIG. 8 — RELATIVE PERMEABILITY RATIO FOR A BARTLESVILLE SANDSTONE CORE.

APPLICATION TO WATER FLOODING OR WATER DRIVE

The method described in this paper can be applied equally well to the evaluation of oil recovery by linear water flooding or water drive. In fact, as mentioned previously, it is of historical interest that the two basic relations employed by the author were first derived by Buckley and Leverett[1,2] in connection with water-oil displacement. In general, all of the basic principles derived by them are equally applicable to the cases of displacement of oil by gas or by water.

In the case of water flooding, however, it is frequently found that the last term in Equation (1), containing the contribution of gravity, is of negligible importance unless the angle of dip is comparatively large or the flow velocity relatively small, or both. This is true because the viscosity of water as the driving fluid replaces the smaller gas viscosity in the denominator of the non-dimensional coefficient H. The change in the value of $\triangle D$, the density difference between water and oil, further operates to reduce the importance of the gravitation term.

If the gravity term is found to be negligible, there will theoretically be no advantage resulting from injecting all of the water at the base of the structure. In this event the calculations may be taken to suggest that the flooding may as well be more quickly completed by employing a pattern of injection wells such as the 5-spot, for example. One possible way of calculating oil recovery in such a flooding program is to base the computations on a unit area served by one injection and one producing well. The distance between these two wells may be taken as L, the sand length, and the average breadth of the sand section is taken such that its product with L is equal to the area of the unit considered. In other words, the actual pattern unit is considered replaced by a linear sand section of equal length and of the same average breadth.

In the case of water flooding or water drive, there is present in the reservoir an initial saturation of the driving fluid (the connate water). The presence of this saturation alters the construction in Fig. 2 in two ways. First, it is more convenient now to consider the entire pore space as receiving the fluid flow, rather than only the hydrocarbon occupied space as before. Second, because of the initial saturation (connate water) of the driving liquid, the considerations described in connection with the tangent construction in Fig. 2 now require that the tangent be drawn from a point on the f curve lying at the height of the original water saturation, rather than from the origin. In general, this point will also lie on the saturation axis, since the connate water is usually immobile. The height of the point of tangency to the f curve now gives the water saturation at the outflow face just after the time of water break-through, and the slope of the tangent can be used to give the flowing water/oil ratio just after break-through. After break-through, the calculations are based primarily on the f curve above the point of tangency, and are made in the same manner as those illustrated in Tables I or II.

ACKNOWLEDGMENTS

The author wishes to thank the management of The Carter Oil Co. for permission to publish this paper. Charles D. Russell, D. R. Shreve, K. H. Andreson, L. W. Welch and W. A. Bain have assisted with suggestions and calculations.

NOMENCLATURE

c = Viscosity of reservoir oil ÷ viscosity of reservoir gas
D_g = Gas density
D_{oil} = Oil density
$\triangle D$ = Oil density less gas density, or water density less oil density
f = Fraction of gas in flowing stream
f_{oil} = Fraction of oil in flowing stream
g = Gravitational constant
h = k_{oil}/k_g
H = $\dfrac{K \triangle D\, g \sin\theta}{\mu_g V_o}$ (dimensionless)
k_g = Relative permeability to gas with connate water in place
k_{oil} = Relative permeability to oil with connate water in place
K = Total permeability to oil with connate water in place
L = Total length of idealized sand section or reservoir
Q_i = Cumulative gas injection in pore volumes
π = Fractional hydrocarbon occupied porosity
S = Gas saturation, fraction of hydrocarbon occupied space
S_{av} = Average gas saturation in reservoir
t = Time
v_o = Velocity of gas approach to sand face = velocity of gas and oil stream after leaving outlet sand face
v = v_o/π
x = Distance from inlet face of system
θ = Average angle of stratum dip
μ_g = Gas viscosity
μ_{oil} = Oil viscosity

REFERENCES

1. Leverett, M. C.: "Capillary Behavior in Porous Solids," *Trans.* AIME, (1941) **142**, 152.
2. Buckley, S. E., and Leverett, M. C.: "Mechanism of Fluid Displacement in Sands," *Trans.* AIME, (1942) **146**, 107.
3. Brinkman, H. C.: "Calculations on the Flow of Heterogeneous Mixtures Through Porous Media." *App. Sci. Res.*, Netherlands, (1949) **A1** (No. 5-6), 333.
4. Muskat, M.: *Physical Principles of Oil Production*, (1949) 496.
5. Rapoport, L. A., and Leas, W. J.: "Relative Permeability to Liquid in Liquid — Gas Systems," *Trans.* AIME, (1951) **192**, 83.
6. Welge, H. J.: "Displacement of Oil from Porous Media by Water or Gas," *Trans.* AIME, (1949) **179**, 133.
7. Rose, W. D., and Bruce, W. A.: "Evaluation of Capillary Character in Petroleum Reservoir Rock," *Trans.* AIME, (1949) **186**, 127.

★ ★ ★

EQUILIBRIUM VAPORIZATION RATIOS FOR NITROGEN, METHANE, CARBON DIOXIDE, ETHANE AND HYDROGEN SULFIDE IN ABSORBER OIL—NATURAL GAS AND CRUDE OIL—NATURAL GAS SYSTEMS

R. H. JACOBY AND M. J. RZASA, MEMBER AIME, STANOLIND OIL AND GAS CO., TULSA, OKLA.

ABSTRACT

Experimental equilibrium vaporization ratios (*K* values) were obtained for nitrogen, methane, carbon dioxide, ethane and hydrogen sulfide in two natural gas-absorber oil mixtures and in two natural gas-Elk Basin crude oil mixtures. For each mixture of constant over-all composition, data were obtained at 100°, 150° and 200°F and at various pressures in the range 200 to 5,000 psia. Some effects of composition on the *K* values were obtained to serve as a guide in choosing *K*'s for engineering calculations on other mixtures.

The pressure cell used to obtain the data is a new type and is described here for the first time.

INTRODUCTION

The phase equilibria of complex hydrocarbon mixtures such as natural gases, crude oils and their mixtures have been studied previously for the purpose of finding equilibrium vaporization ratios for the hydrocarbon constitutents. In a few cases, such non-hydrocarbons as nitrogen, carbon dioxide, and hydrogen sulfide were included in the mixtures studied because they occur in the fluids obtained from petroleum reservoirs.

The increasing occurrence of these non-hydrocarbons and their growing economic importance, make it necessary to account for them more accurately in engineering calculations than is now possible using the meager published data.

The available data for non-hydrocarbons may be classified into two groups: namely, binary mixtures of a hydrocarbon and a non-hydrocarbon, and mixtures containing three or more components, only one of which is a non-hydrocarbon. Among the former, phase analyses are available for two nitrogen-*HC* mixtures, five carbon dioxide-*HC* mixtures and three hydrogen sulfide-*HC* mixtures. Data for more complex mixtures are available as follows: Nitrogen-Methane-Pentane[1]; Nitrogen-Methane-Hexane[2]; Nitrogen-Methane-Heptane[2]; Carbon dioxide-Natural Gas-Natural Gasoline[4]; Carbon dioxide-Natural Gas-Crude Oil[5].

These data have been used generally for engineering calculations, often with little regard for their precise applicability because data for the non-hydrocarbons in the complex mixtures being dealt with were not available. The use of *K* values from binary data for calculations involving complex mixtures is open to criticism because such *K*'s are not a function of composition and very often show large differences from the *K*'s for the same components in a complex mixture.

Thus the effects of composition must be evaluated when obtaining *K*'s for components in complex mixtures. Poettmann and Katz[4,5] varied the carbon dioxide content of their mixtures from about five to ten mol per cent and found substantially no effect on the *K* values due to this change. This was not surprising since one might expect that changing a minor component by ± three mol per cent would have little effect. It is more important to find the composition changes which have the largest effect on the *K* values. For example, varying the methane or heptanes — plus compositions over a wide range may have a large effect on the *K*'s of all components in the mixture. Interesting data to this effect were obtained by Eilerts and Smith.[6]

It was toward these problems that the experimental data presented here were directed.

EQUIPMENT

The pressure cell used to obtain the data is somewhat different from those which have been described in the past. Photographs of the equipment are shown in Figs. 1 and 2. Fig. 1 shows the front panel: from a seated position at the right the

[1]References given at end of paper.

Manuscript received in the Petroleum Branch office Aug. 25, 1951. Paper presented at the Fall Meeting of the Petroleum Branch in Oklahoma City, Okla., Oct. 3-5, 1951.

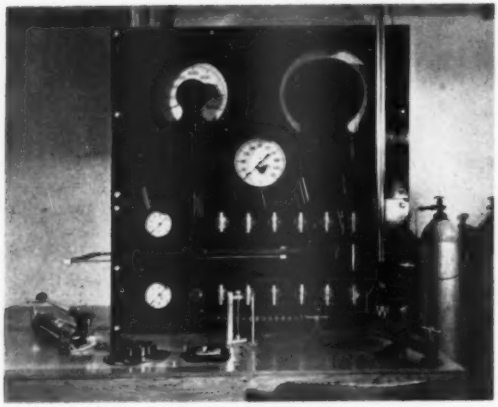


FIG. 1 — FRONT VIEW OF EQUIPMENT SHOWING ALL CONTROLS.

operator has access to all controls necessary to operate the cell. A schematic flow sheet of the equipment is shown in Fig. 3.

The cell itself consists of a hollow stainless steel (AISI Type 316) cylinder fitted with a piston and placed in a horizontal position. The end of the cylinder through which the piston rod projects is sealed by a steel plug having a tool-joint thread; pressure seals are an unsupported area type at the cylinder wall and V-rings around the piston rod. The head end of the cylinder is fitted with a glass window sealed with O-rings, a steel back-up plate, and a steel plug with a tool-joint thread. Fig. 2 shows the assembly of these parts and the head end of the cell. The space between the piston head and the glass window is used to contain the mixtures being investigated. The metal parts of the head assembly are provided with a slit so that the cell contents can be seen through the glass window. The principal auxiliaries are a pressure intensifier, injector cell, hot air bath, cathetometer, vacuum pump and magnetic pump for circulating the fluid mixture in the cell.

The cell volume may be varied from 40 to 1,200 cc and steel parts of the cell were designed to make it operable at 25,000 psia and 500°F. In its present state, however, certain pressure seals employing rubber or Teflon limit use of the cell to temperatures nearer 300°F.

EXPERIMENTAL PROCEDURE

Experimental runs were made as follows: a mixture of appropriate composition was made up by charging the components to the cell one at a time. First, hydrogen sulfide was measured directly into the windowed cell after flushing the cell several times. Other gaseous components were then charged with the injector cell. For each gas, the evacuated injector was filled with gas from a cylinder and measured volumes of this gas were then displaced into the windowed cell at a known pressure. The liquid component of the mixture was the last one to be charged. From measurements of volume, pressure and temperature and molar volume data on the components, the amounts charged were calculated.

A mixture so charged was then heated and pressured to desired conditions and the cell liquid circulated with the magnetic pump until no further changes in pressure could be observed at constant volume and temperature. When equilibrium was thus attained the pump was shut off and samples of the liquid and vapor phases displaced into 100 cc sample bombs while holding the equilibrium pressure on the cell contents. The amounts of the phases drawn off for sample were proportional to the amounts existing in the cell at equilibrium conditions. In this way the overall composition remaining in the cell after sampling both phases was substantially the same as the original mixture charged to the cell. Thus by changing to another set of equilibrium conditions (change of pressure only in most cases) additional sets of phase samples could be obtained without recharging the cell. Calculations made from the charging measurements showed that the compositions given in Table II were consistently reproduced within ± 0.5 mol per cent of any component.

FIG. 2 — END VIEW OF CELL SHOWING THE GLASS WINDOW AND HEAD END ASSEMBLY.

Analysis of Samples

Vapor samples were analyzed directly by the mass spectrometer. In a number of runs, the sample bombs were not filled at the pressure of operation and the bomb was outside the air bath at room temperature. It was thus possible to encounter dew point conditions for the vapor being sampled. After a portion of the vapor sample was taken for analysis by mass spectrometer, the remainder was flashed away to the atmosphere and the bombs examined for dew-point liquid.

For many of the absorber oil vapor samples above 2,000 psia operating pressure the inside surface of the bombs was wet with a film of liquid; the greatest amount of liquid thus

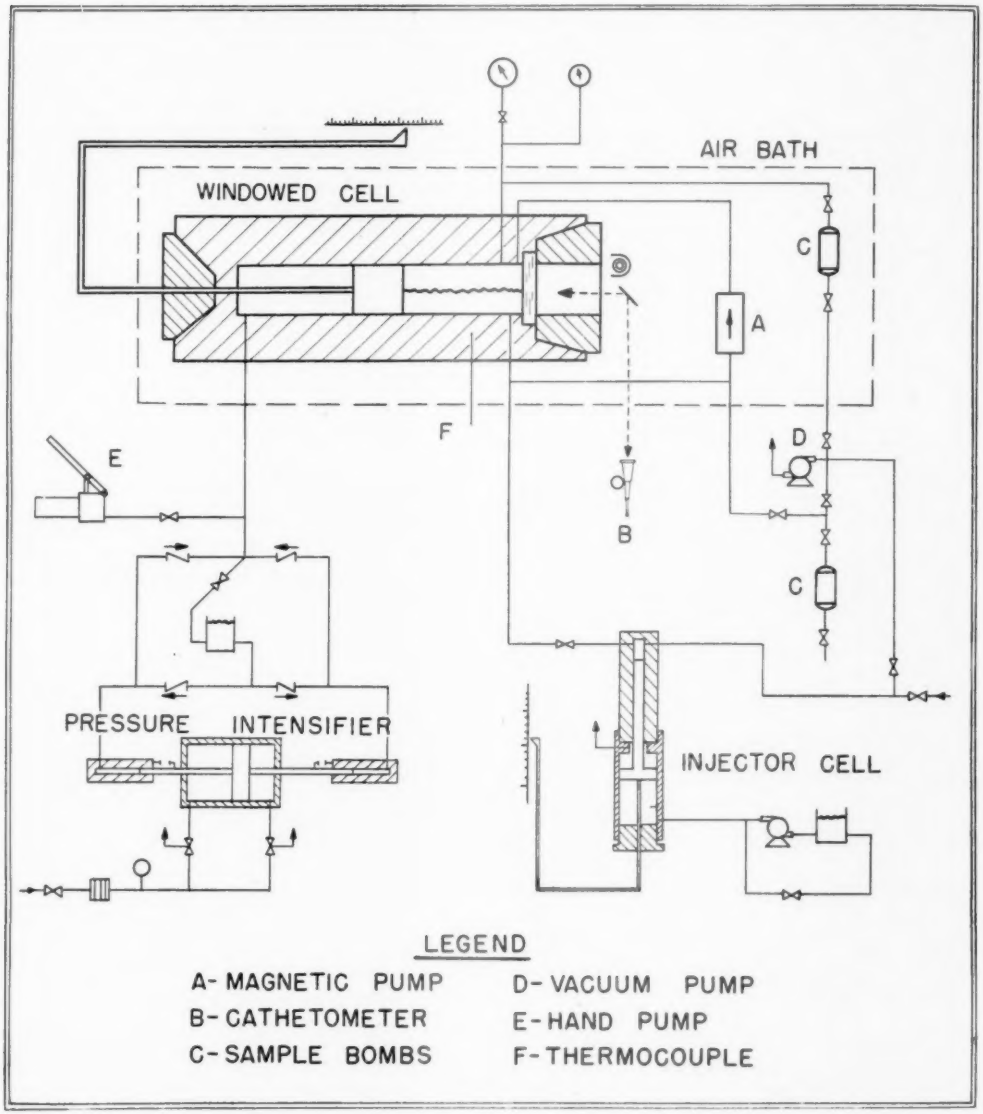


FIG. 3 – SCHEMATIC FLOW SHEET OF CELL AND ASSOCIATED EQUIPMENT.

Table I — Analyses of Materials Used to Make Up the Mixtures Shown in Table II

	Natural Gas	Absorber Oil	Crude Oil
Nitrogen	2.28 mol %		
Methane	95.78		
Ethane	1.74		
Propane	0.20		
Isobutane			0.09 mol %
n-Butane			0.67
Isopentane			2.68
n-Pentane			2.52
Hexanes			2.44
Heptanes - plus			91.60
MW C_7+			227
Sp. Gr. 60/60 C_7+			0.894
Mol. Wt.		1.77	224
Sp. Gr. 60/60		0.835	0.882

observed appeared to be about 0.5 cc and could not be recovered for measurement. The mass spectrometer analysis was then considered as the vapor analysis. Estimates were made of the C_7+ content of the vapor and they varied from 0.4 mol per cent at 2,000 psia and 100°F to 5 mol per cent at 5,000 psia and 100°F. These estimates are a measure of the error to be encountered if all the C_7+ had been omitted from the reported analyses as a result of the sampling procedure used.

Similar observations were made on vapor samples from the crude oil mixtures and in no case were any traces of liquid found in the bombs. The mass spectrometer analyses thus represent the actual vapor compositions to the limits of accuracy of the spectrometer.

The liquid samples were analyzed by charging to a low temperature Podbielniak column which flashed off the C_7-and-lighter components essentially as a fraction. The volume of this fraction was measured on the Pod column and it was then analyzed by mass spectrometer. The remainder of the liquid samples heavier-than-C_7 was then fractionated through hexanes, and specific gravity and cryoscopic molecular weight of the C_7+ fraction were measured. From these data the liquid analyses were computed.

Materials

The components used to make up the mixtures were: Matheson pre-purified nitrogen, natural gas (Matheson 96 per cent methane), Matheson bone-dry carbon dioxide, Matheson hydro-

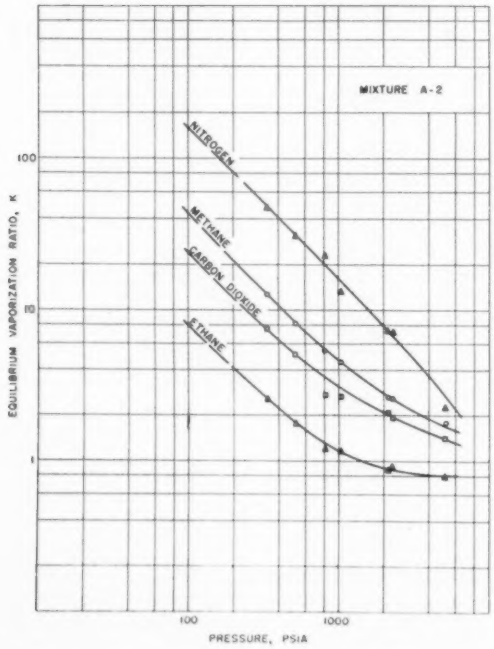


FIG. 4 — K VALUES IN ABSORBER OIL MIXTURE A-2 AT 100°F.

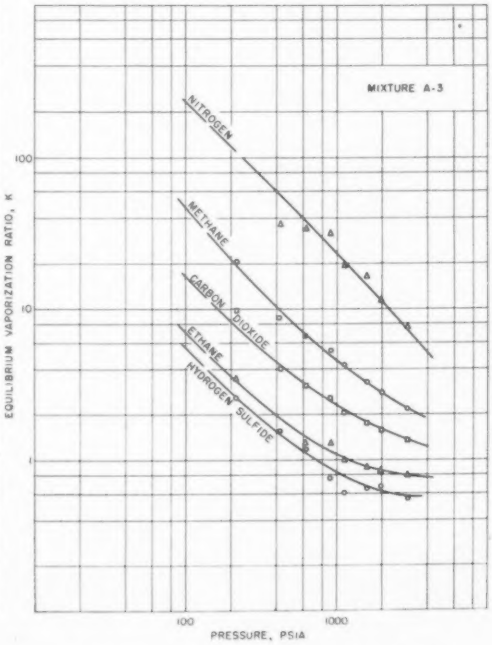


FIG. 5 — K VALUES IN ABSORBER OIL MIXTURE A-3 AT 100°F.

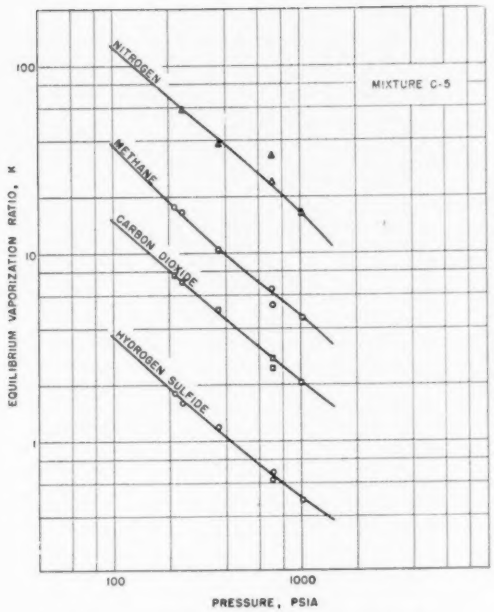


FIG. 6 — K VALUES IN CRUDE OIL MIXTURE C-5 AT 100°F.

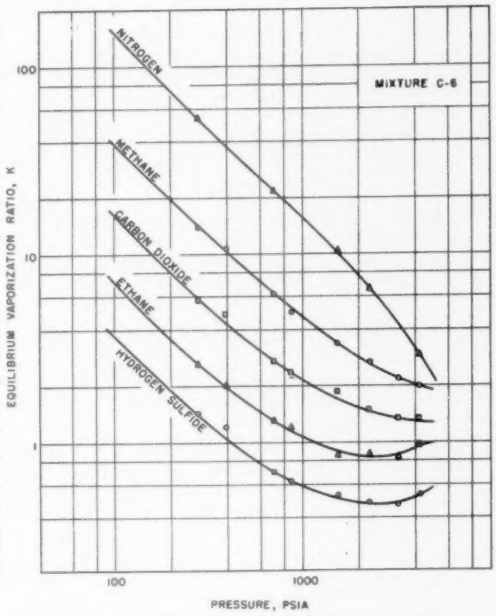


FIG. 7 — K VALUES IN CRUDE OIL MIXTURE C-6 AT 100°F.

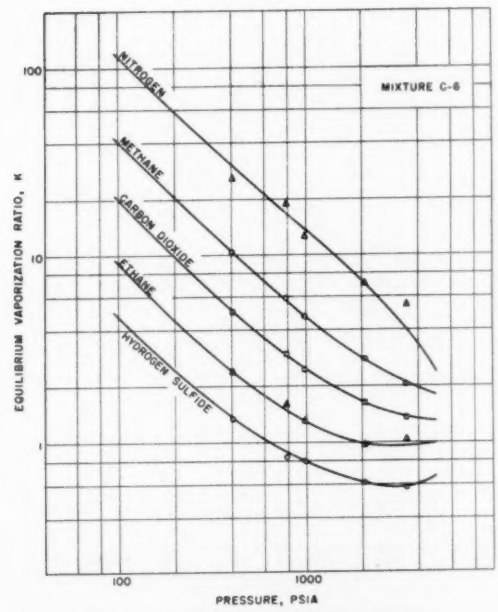


FIG. 8 — K VALUES IN CRUDE OIL MIXTURE C-6 AT 150°F.

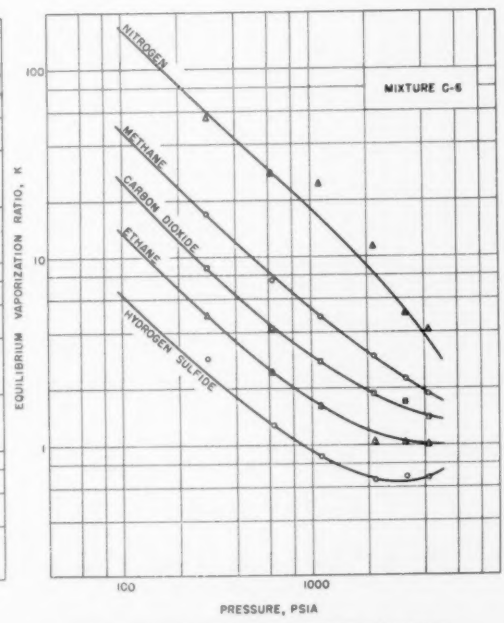


FIG. 9 — K VALUES IN CRUDE OIL MIXTURE C-6 AT 200°F.

gen sulfide, lean absorber oil from Stanolind's Hastings gasoline plant, and crude oil from the Tensleep formation in Elk Basin, Wyoming. Samples of the nitrogen, carbon dioxide, and hydrogen sulfide were checked for purity by mass spectrometer and found to be essentially 99.9 per cent pure. Analyses of the other materials are shown in Table I.

RESULTS

The mixtures studied in this work were natural gas-absorber oil and natural gas-crude oil, to each of which small amounts of nitrogen, carbon dioxide and hydrogen sulfide were added. Two different absorber oil mixtures and two crude oil mixtures were used; the overall compositions of these are shown in Table II. For each of the four mixtures, phase analyses were obtained over a range of pressures at 100°F, 150°F and 200°F.

Table II — Overall Compositions of Mixtures Studied

	Absorber Oil		Crude Oil	
Component	A-2	A-3	C-5	C-6
Nitrogen	10.0 mol %	10.0 mol %	5.0 mol %	5.0 mol %
Natural Gas	65.0	40.0	10.0	40.0
Carbon Dioxide	5.0	5.0	5.0	5.0
Hydrogen Sulfide		5.0	5.0	5.0
Absorber or Crude Oil	20.0	40.0	75.0	45.0

Table III — Equilibrium Flash Vaporization Data

Pressure psia	A-2 Mixture 100°F	A-2 Mixture 200°F	A-3 Mixture 100°F	A-3 Mixture 200°F	C-5 Mixture 100°F	C-5 Mixture 200°F	C-6 Mixture 100°F	C-6 Mixture 200°F
	VOLUME PER CENT LIQUID							
200	3.5	2.5	7.9	6.4	37.2	31.1	16.3	10.7
500	9.0	6.7	20.0	17.2	68.8	62.0	26.2	22.7
1,000	14.8	13.1	37.2	33.2	92.8	86.8	45.0	40.0
1,500	22.5	20.1	51.5	46.2			62.0	54.0
2,000	29.6	26.8	62.0	56.6			75.7	65.4
2,500	35.7	32.6	70.8	64.8			84.2	74.6
3,000	41.0	37.6	77.7	72.0			89.3	82.0
3,500	45.6	42.2					93.3	88.5
4,000	50.0	46.2					96.7	94.5

The experimental phase analyses and the K values calculated from them are given in Tables IV and V. K values were calculated for nitrogen, methane, carbon dioxide, ethane and hydrogen sulfide. The hydrocarbons from propane through hexane were present to such a small extent that reliable analyses for them in both phases were not obtained, and hence K's were not calculated for them. In Table IV, "trace com-

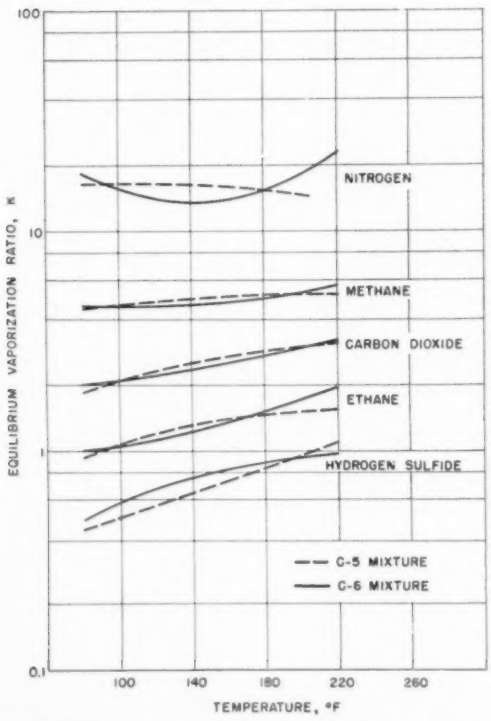


FIG. 10 — COMPARISON OF K'S IN CRUDE OIL MIXTURES C-5 AND C-6 AT 1,000 PSIA.

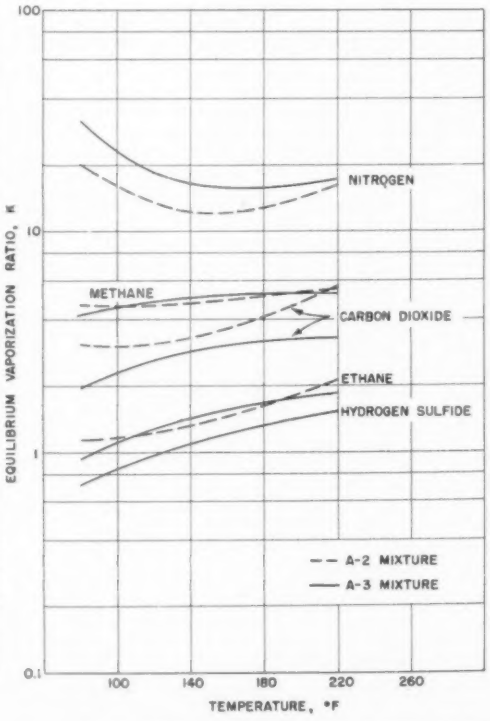


FIG. 11 — COMPARISON OF K'S IN ABSORBER OIL MIXTURES A-2 AND A-3 AT 1,000 PSIA.

Table IV — Experimental Data for Absorber Oil Mixtures

Run No.	Temp. °F	Pres. psia	Nitrogen x	Nitrogen y	Nitrogen K	Methane x	Methane y	Methane K	Carbon Dioxide x	Carbon Dioxide y	Carbon Dioxide K	Ethane x	Ethane y	Ethane K	Hydrogen Sulfide x	Hydrogen Sulfide y	Hydrogen Sulfide K	Trace Comp. x	Trace Comp. y	Heptanes-plus x	Heptanes-plus y	Heptanes-plus Sp. Gr. 60/60	Heptanes-plus MW
A-2 MIXTURE																							
84	98.2	336	.0032	.1517	47.4	.0608	.7559	12.43	.0097	.0723	7.45	.0051	.0129	2.53				.0052	.0072	.9160	....	0.838	176
82	99.2	519	.0048	.1468	30.6	.0933	.7631	8.18	.0144	.0724	5.03	.0072	.0126	1.75				.0127	.0051	.8676	....	0.839	175
90	99.4	813	.0065	.1483	22.8	.1425	.7661	5.376	.0269	.0733	2.72	.0086	.0103	1.20				.0036	.0020	.8119	....	0.839	178
80	100.1	1029	.0102	.1329	13.03	.1725	.7755	4.496	.0270	.0718	2.66	.0106	.0123	1.16				.0189	.0075	.7608	....	0.837	173
81	97.4	2121	.0222	.1612	7.26	.2825	.7470	2.644	.0311	.0649	2.09	.0125	.0109	0.872				.0094	.0160	.6423	....	0.838	171
83	100.2	2275	.0249	.1783	7.16	.2871	.7267	2.531	.0412	.0786	1.91	.0116	.0106	0.914				.0152	.0058	.6200	....	0.838	171
89	99.4	5119	.0524	.1166	2.23	.4492	.7994	1.780	.0516	.0721	1.40	.0117	.0093	0.79				.0083	.0026	.4268	....	0.839	177
171	151.3	309	.0055	.1921	34.9	.0469	.7192	15.33	.0065	.0727	11.2	.0029	.0113	3.90				.0031	.0047	.9351	....	0.837	173
169	150.6	609	.0098	.1775	18.1	.0979	.7309	7.47	.0136	.0761	5.60	.0058	.0109	1.88				.0053	.0046	.8676	....	0.838	177
167	150.2	970	.0130	.1602	12.3	.1494	.7445	4.983	.0141	.0639	4.53	.0070	.0110	1.57				.0113	.0204	.8052	....	0.838	175
166	149.8	2237	.0276	.1683	6.10	.2770	.7427	2.68	.0339	.0625	1.84	.0095	.0099	1.04				.0063	.0166	.6457	....	0.838	173
170	150.6	5069	.0765	.2229	2.91	.4079	.7047	1.728	.0482	.0620	1.29	.0082	.0079	0.96				.0124	.0025	.4468	....	0.838	173
87	200.7	535	.0053	.1588	30.0	.0848	.7493	8.84	.0076	.0721	9.49	.0042	.0140	3.33				.0072	.0058	.8909	....	0.835	178
92	202.2	794	.0067	.1410	21.0	.1184	.7734	6.532	.0149	.0722	4.85	.0054	.0112	2.07				.0047	.0022	.8499	....	0.838	174
85	200.0	1111	.0127	.1581	12.4	.1542	.7452	4.833	.0169	.0742	4.39	.0065	.0113	1.74				.0080	.0112	.8017	....	0.838	174
86	201.0	2070	.0260	.1653	6.36	.2577	.7424	2.881	.0234	.0676	2.89	.0107	.0126	1.18				.0173	.0121	.6649	....	0.838	179
91	198.9	4914	.0441	.1562	3.54	.4599	.7661	1.666	.0386	.0669	1.73	.0096	.0095	0.99				.0088	.0013	.4390	....	0.838	181
A-3 MIXTURE																							
110	100.6	218	.0005	.1824	.....	.0309	.6325	20.5	.0093	.0916	9.85	.0025	.0087	3.5	.0316	.0813	2.57	.0017	.0035	.9205	....	0.838	176
98	99.4	425	.0045	.1649	36.6	.0739	.6543	8.85	.0238	.0971	4.08	.0045	.0025	....	.0311	.0485	1.56	.0059	.0397	.8563	....	0.838	178
100	100.6	630	.0063	.2161	34.3	.0963	.6388	6.63	.0295	.0923	3.13	.0050	.0063	1.3	.0368	.0437	1.19	.0115	.0028	.8146	....	0.838	177
94*	99.3	792	.0084	.1985	23.6	.1295	.7066	5.456	.0251	.0784	3.12	.0058	.0080	1.38	.....	.....	.....	.0016	.0085	.8296	....	0.837	180
109	101.9	917	.0068	.2164	31.8	.1204	.6485	5.386	.0329	.0849	2.58	.0050	.0065	1.3	.0531	.0405	0.763	.0039	.0032	.7779	....	0.838	173
95	100.7	1108	.0094	.1821	19.4	.1678	.7189	4.284	.0326	.0667	2.05	.0068	.0068	1.0	.0394	.0238	0.604	.0016	.0017	.7424	....	0.838	176
97	99.5	1591	.0134	.2299	16.5	.2031	.6688	3.293	.0464	.0812	1.75	.0062	.0056	0.90	.0341	.0221	0.648	.0116	.0014	.6852	....	0.838	179
96	100.2	1977	.0211	.2430	11.5	.2317	.6451	2.78	.0495	.0783	1.58	.0063	.0054	0.86	.0390	.0259	0.664	.0040	.0033	.6484	....	0.838	175
93*	100.8	2000	.0233	.2115	9.08	.2505	.7092	2.831	.0400	.0712	1.78	.0070	.0059	0.84	.....	.....	.....	.0015	.0022	.6777	....	0.838	178
99	100.6	2979	.0371	.2829	7.63	.2837	.6128	2.160	.0559	.0750	1.34	.0063	.0050	0.79	.0387	.0213	0.55	.0058	.0030	.5725	....	0.838	175
114	150.3	303	.0041	.1902	46.4	.0389	.6016	15.5	.0121	.0984	8.13	.0023	.0082	3.6	.0346	.0947	2.74	.0044	.0069	.9036	....	0.837	179
107	151.3	611	.0099	.2084	21.1	.0803	.6258	7.79	.0223	.1010	4.53	.0040	.0075	1.88	.0312	.0544	1.74	.0102	.0029	.8421	....	0.838	176
111	151.8	960	.0105	.2008	19.1	.1242	.6505	5.24	.0316	.0939	2.97	.0046	.0070	1.5	.0431	.0436	1.01	.0056	.0042	.7804	....	0.838	176
106	151.4	1092	.0162	.2244	13.9	.1358	.6286	4.629	.0294	.0956	3.25	.0051	.0069	1.4	.0302	.0423	1.40	.0098	.0022	.7745	....	0.838	177
113	150.8	1556	.0224	.2350	10.5	.1712	.6111	3.570	.0438	.0868	1.98	.0052	.0060	1.2	.0677	.0572	0.845	.0102	.0039	.6795	....	0.837	173
108	150.8	2171	.0343	.2614	7.62	.2177	.6152	2.83	.0478	.0833	1.74	.0065	.0055	0.85	.0479	.0320	0.668	.0045	.0026	.6413	....	0.838	175
118	200.2	206	.0024	.1961	81.7	.0258	.6059	23.5	.0076	.0969	12.8	.0017	.0102	6.0	.0177	.0870	4.92	.0038	.0039	.9410	....	0.838	174
103	201.4	377	.0020	.1556	77.8	.0497	.6432	12.9	.0131	.0991	7.56	.0025	.0089	3.6	.0296	.0814	2.75	.0128	.0118	.8903	....	0.838	174
117	199.6	516	.0061	.2073	34.0	.0646	.6179	9.57	.0169	.0938	5.55	.0037	.0091	2.5	.0299	.0664	2.22	.0042	.0055	.8746	....	0.838	174
115	201.7	884	.0121	.2325	19.2	.1063	.6137	5.77	.0283	.0957	3.38	.0045	.0083	1.8	.0340	.0460	1.35	.0060	.0018	.8088	....	0.837	173
102	200.5	1000	.0145	.1830	12.7	.1247	.6681	5.358	.0268	.0927	3.46	.0045	.0079	1.8	.0283	.0448	1.58	.0139	.0029	.7873	....	0.838	177
116	199.3	1604	.0240	.2432	10.1	.1607	.6169	3.84	.0366	.0872	2.38	.0055	.0076	1.4	.0376	.0422	1.12	.0077	.0029	.7279	....	0.838	173
101	201.2	2057	.0318	.2062	6.48	.2033	.6582	3.238	.0424	.0861	2.03	.0054	.0071	1.31	.0363	.0378	1.04	.0069	.0046	.6739	....	0.838	177
105	200.3	2993	.0384	.2652	6.91	.2068	.5988	2.896	.0467	.0819	1.75	.0049	.0062	1.3	.0475	.0399	0.84	.0036	.0080	.6521	....	0.838	175

*The mixtures used in these runs contained no hydrogen sulfide.

Table V — Experimental Data for Crude Oil Mixtures

Run No.	Temp. °F	Pres. psia	Nitrogen x	Nitrogen y	Nitrogen K	Methane x	Methane y	Methane K	Carbon Dioxide x	Carbon Dioxide y	Carbon Dioxide K	Ethane x	Ethane y	Ethane K	Hydrogen Sulfide x	Hydrogen Sulfide y	Hydrogen Sulfide K	C_3-C_5 x	C_3-C_5 y	Heptanes-plus* x	Heptanes-plus* y	Heptanes-plus* Sp. Gr. 60/60	Heptanes-plus* MW
C-5 MIXTURE																							
139	99.4	214	.0000	.2544	.....	.0256	.4532	17.7	.0270	.2068	7.66	.0012	.0032	2.67	.0399	.0718	1.80	.1061	.0106	.8002	.....	0.895	252
165	100.7	236	.0046	.2710	58.9	.0269	.4469	16.6	.0284	.2010	7.08	.0011	.0031	2.8	.0437	.0701	1.60	.1024	.0079	.7929	.....	0.897	250
133	101.5	369	.0086	.3302	38.4	.0433	.4517	10.4	.0324	.1625	5.02	.0014	.0035	2.5	.0388	.0461	1.19	.0976	.0060	.7779	.....	0.899	255
140	99.7	713	.0167	.3986	23.9	.0792	.4247	5.36	.0561	.1375	2.45	.0018	.0014	0.78	.0509	.0320	0.629	.0809	.0058	.7144	.....	0.896	252
124	100.0	713	.0117	.3889	33.2	.0704	.4525	6.43	.0449	.1236	2.75	.0015	.0021	1.4	.0414	.0282	0.681	.0674	.0047	.7627	.....	(0.894)	(247)
134	100.5	1019	.0296	.4767	16.1	.0854	.3873	4.54	.0512	.1052	2.05	.0001	.0015	.....	.0493	.0240	0.487	.0852	.0053	.6992	.....	0.896	256
128	150.0	230	.0038	.2437	64.1	.0266	.4417	16.6	.0202	.1960	9.70	.0010	.0038	3.8	.0386	.0912	2.36	.0661	.0236	.8437	.....	(0.886)	(243)
141	150.0	416	.0072	.3081	42.8	.0075	.4612	9.71	.0328	.1632	4.98	.0015	.0035	2.33	.0378	.0521	1.38	.0665	.0119	.8067	.....	0.894	251
127	149.4	514	.0082	.3057	37.3	.0555	.4625	8.33	.0395	.1658	4.20	.0015	.0014	0.93	.0432	.0521	1.21	.0681	.0125	.7840	.....	(0.886)	(242)
125	149.6	813	.0154	.3928	25.5	.0626	.4307	6.88	.0422	.1331	3.15	.0014	.0011	0.78	.0452	.0356	0.788	.0442	.0067	.7890	.....	(0.890)	(243)
136	150.5	963	.0248	.3888	15.7	.0849	.4422	5.21	.0461	.1247	2.70	.0016	.0022	1.38	.0483	.0340	0.704	.0771	.0081	.7172	.....	0.895	250
129	150.3	1062	.0280	.4332	15.5	.0834	.3942	4.73	.0513	.1227	2.39	.0015	.0026	1.73	.0451	.0337	0.747	.0769	.0136	.7138	.....	(0.888)	(243)
163	150.3	1285	.0362	.4811	13.3	.0904	.3574	3.95	.0557	.1198	2.15	.0015	.0018	1.2	.0449	.0281	0.626	.0824	.0118	.6889	.....	0.896	250
137	201.7	229	.0033	.2127	64.5	.0196	.4511	23.0	.0151	.1977	13.1	.0008	.0041	5.1	.0272	.1066	3.92	.0925	.0278	.8415	.....	0.896	252
130	200.6	514	.0104	.2750	26.4	.0461	.4575	9.92	.0317	.1797	5.67	.0013	.0038	2.9	.0359	.0690	1.92	.0908	.0150	.7838	.....	0.895	250
132	201.5	793	.0188	.3321	17.7	.0734	.4591	6.25	.0394	.1380	3.50	.0016	.0032	2.0	.0472	.0529	1.12	.0832	.0147	.7364	.....	0.896	251
131	202.0	1034	.0255	.3656	14.3	.0885	.4528	5.12	.0429	.1249	2.91	.0018	.0025	1.4	.0456	.0434	0.952	.0801	.0108	.7156	.....	0.895	250
138	201.8	1351	.0399	.3964	9.93	.1072	.4242	3.957	.0512	.1251	2.44	.0018	.0018	1.0	.0366	.0403	1.10	.0483	.0122	.7150	.....	0.896	252
C-6 MIXTURE																							
159	99.5	279	.0018	.0970	53.9	.0523	.7284	13.9	.0183	.1054	5.76	.0037	.0098	2.6	.0352	.0501	1.42	.0752	.0093	.8135	.....	0.898	250
145	100.2	392	.0010	.1069	.....	.0707	.7464	10.6	.0175	.0840	4.80	.0043	.0084	2.0	.0385	.0461	1.20	.1051	.0082	.7629	.....	0.897	255
160	99.9	701	.0049	.1064	21.7	.1244	.7603	6.112	.0321	.0864	2.69	.0062	.0080	1.3	.0501	.0350	0.699	.0833	.0039	.6990	.....	0.897	250
143	100.9	867	.0015	.1127	.....	.1556	.7634	4.906	.0298	.0696	2.34	.0065	.0076	1.2	.0512	.0316	0.617	.0721	.0151	.6833	.....	0.894	250
144	98.7	1548	.0127	.1318	10.4	.2285	.7636	3.342	.0349	.0646	1.85	.0075	.0064	0.85	.0521	.0270	0.518	.0901	.0066	.5742	.....	0.894	252
146	100.6	2277	.0184	.1196	6.50	.2884	.7693	2.667	.0473	.0697	1.47	.0074	.0064	0.86	.0052	.0261	0.473	.0641	.0089	.5192	.....	0.895	251
147	99.1	3228	.0248	.1702	6.86	.3399	.7298	2.147	.0470	.0619	1.32	.0075	.0062	0.83	.0470	.0218	0.464	.0590	.0101	.4748	.....	0.895	250
148	99.2	4166	.0578	.1676	2.90	.3683	.7306	1.984	.0459	.0605	1.32	.0070	.0067	0.96	.0404	.0212	0.525	.0524	.0134	.4282	.....	0.895	252
158	149.8	406	.0035	.0906	25.9	.0703	.7329	10.4	.0213	.1060	4.98	.0039	.0095	2.4	.0365	.0490	1.34	.0822	.0120	.7823	.....	0.894	250
157	150.3	783	.0053	.0996	18.8	.1264	.7412	5.864	.0341	.1009	2.96	.0054	.0087	1.6	.0456	.0383	0.840	.0583	.0113	.7249	.....	0.896	251
154	149.3	982	.0097	.1228	12.7	.1552	.7279	4.690	.0398	.0974	2.45	.0064	.0081	1.3	.0445	.0351	0.789	.0827	.0087	.6617	.....	0.899	250
155	149.4	2068	.0200	.1404	7.02	.2621	.7279	2.777	.0545	.0880	1.61	.0069	.0067	0.97	.0450	.0273	0.607	.0725	.0097	.5390	.....	0.899	250
156	151.1	3453	.0287	.1554	5.41	.3588	.7216	2.011	.0608	.0826	1.36	.0067	.0070	1.04	.0388	.0223	0.575	.0595	.0111	.4467	.....	0.899	255
162	200.0	283	.0017	.0945	55.6	.0417	.7084	16.99	.0112	.0982	8.77	.0022	.0108	4.91	.0240	.0691	2.88	.0778	.0190	.8414	.....	0.898	251
152	199.6	625	.0039	.1090	27.9	.0963	.7222	7.50	.0267	.1113	4.17	.0011	.0100	2.44	.0317	.0403	1.27	.0755	.0072	.7618	.....	.0894	250
149	198.4	1112	.0041	.1005	24.5	.1534	.7345	4.788	.0400	.1104	2.76	.0057	.0092	1.6	.0414	.0359	0.867	.0826	.0095	.6728	.....	0.897	255
150	199.3	2166	.0113	.1260	11.2	.2472	.7334	2.967	.0513	.0959	1.87	.0069	.0072	1.04	.0418	.0271	0.648	.0648	.0104	.5767	.....	0.894	251
151	199.3	3177	.0276	.1380	5.00	.3267	.7269	2.22	.0578	.0913	1.58	.0068	.0070	1.03	.0365	.0245	0.671	.0586	.0123	.4860	.....	0.895	250
153	198.4	4194	.0406	.1659	4.09	.3801	.7034	1.851	.0641	.0888	1.39	.0065	.0064	1.0	.0360	.0239	0.664	.0544	.0116	.4183	.....	0.895	251

*Values in parentheses ( ) are properties of C_7+ fraction.

ponents" is listed as a component of the phase analyses. This was necessary in order to compact the information from the mass spectrometer analyses. Those analyses reported trace amounts of hydrocarbons between ethane and hexane as well as small amounts of hydrogen, carbon monoxide and sulfur dioxide. It would be dubious to report these individually since the amounts were generally below the limits of good accuracy of the spectrometer. The fractions of these compounds were summed and reported as "trace components."

The pressures and temperatures reported in Tables IV and V are believed accurate within ±10 psia and ±2°F.

The 100°F data for A-2, A-3 and C-5 mixtures are plotted on graphs of log K *vs* log pressure in Figs. 4, 5 and 6. All three isotherms are plotted for C-6 mixture in Figs. 7, 8 and 9. In order to facilitate use of the C-6 data, the log K *vs* log pressure graphs were cross-plotted to obtain log K *vs* temperature graphs for nitrogen, methane, carbon dioxide, ethane and hydrogen sulfide; these are shown in Figs. 12 to 16.

Some equilibrium flash data were obtained from the observations of volume per cent liquid in the cell at equilibrium conditions previous to sampling. These data were plotted as isotherms on a graph of pressure *vs* volume per cent liquid. Readings from these smoothed curves are given in Table III.

DISCUSSION

In addition to finding the variation of the K values with pressure and temperature, it was intended to evaluate composition effects which might be important.

The composition variables discussed in this work refer to overall mixture compositions, z. These were preferred over liquid and vapor compositions (x and y) even though it is necessary to specify one more independent variable than the phase rule requires to completely identify a particular equilibrium of components.

The composition variations made were of two main types, (A) use of both absorber oil and crude oil for the heptanes plus component, and (B) varying the proportions of natural

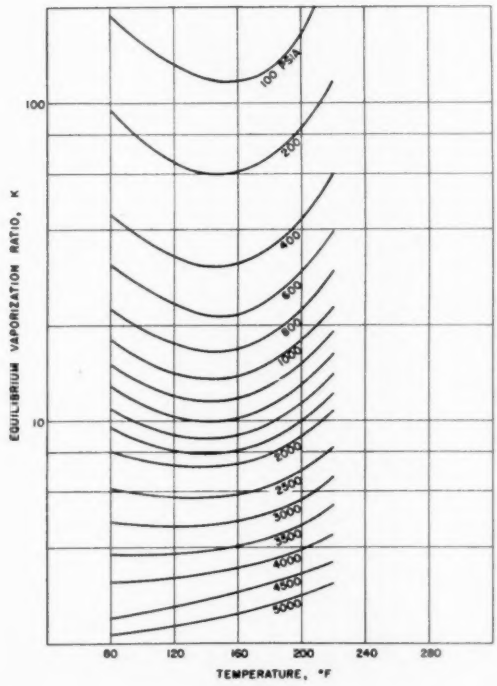


FIG. 12 — NITROGEN K'S IN CRUDE OIL MIXTURE C-6 AS A FUNCTION OF TEMPERATURE AND PRESSURE.

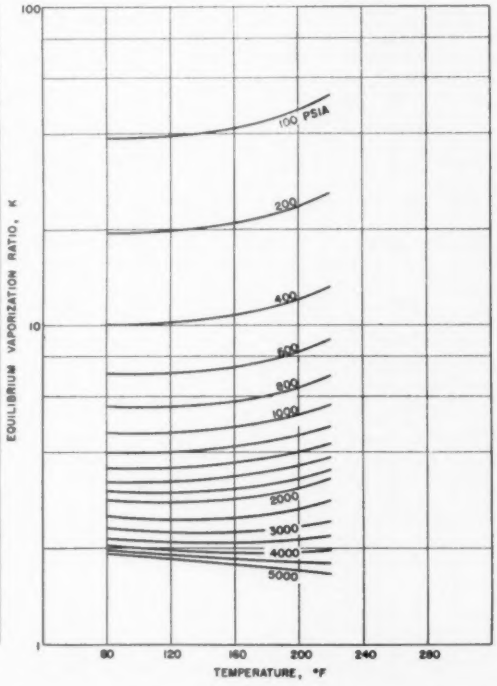


FIG. 13 — METHANE K'S IN CRUDE OIL MIXTURE C-6 AS A FUNCTION OF TEMPERATURE AND PRESSURE.

gas to heptanes plus. The latter was essentially a variation of the gas/oil ratio. An additional variation was introduced in the work on absorber oil mixtures by eliminating hydrogen sulfide from some of the mixtures, *i.e.*, all A-2 mixtures and runs 93 and 94 of A-3 mixture at 100°F. In the composite used in runs 93 and 94, the 5 mol per cent of hydrogen sulfide was replaced with natural gas. This variation was made to provide data for gasoline plant absorbers where the feed gas is free of hydrogen sulfide but many contain nitrogen and carbon dioxide.

The primary graphs of the data are the log K *vs* log pressure curves at constant temperature and composition. Such graphs are not shown for all temperatures and compositions because of the number of them; examples of all compositions are given at 100°F and all temperatures are given for the C-6 composition. These graphs are the best means of showing the data points since the experiments were conducted at constant temperature and composition. On these graphs the convergence effect is shown most by the mixtures of higher bubble point pressure (BPP) at 100°F. Fig. 6 brings out clearly the fact that these curves become discontinuous at the single phase pressure and do not necessarily converge toward $K = 1$ except at the critical temperature of the mixture. Convergence is shown more readily by mixtures of higher BPP at higher pressures where the properties of the phases become more nearly alike and the components show less preference for one phase or the other. The K's thus approach unity.

The effects of composition are more clearly observed on graphs of log K *vs* temperature as in Fig. 10. At 1,000 psia the curve for nitrogen in C-5 was such that $\frac{\partial K}{\partial t}$ became less positive with increase in temperature (concave down; $\frac{\partial^2 K}{\partial t^2}$ is negative) while for C-6 mixture $\frac{\partial K}{\partial t}$ became more positive with increase in temperature (concave up; $\frac{\partial^2 K}{\partial t^2}$ is positive). For nitrogen in the two crude oil mixtures this was true over the pressure range investigated, but in general, the sign of $\frac{\partial^2 K}{\partial t^2}$ depended on the pressure also. Thus the effects of com-

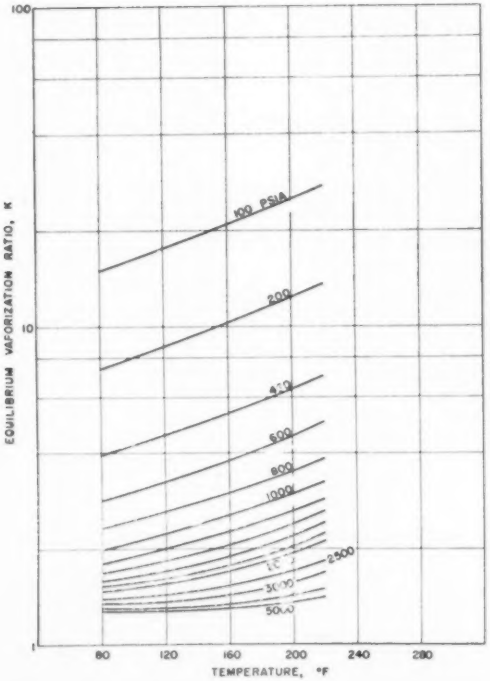


FIG. 14 — CARBON DIOXIDE K'S IN CRUDE OIL MIXTURE C-6 AS A FUNCTION OF TEMPERATURE AND PRESSURE.

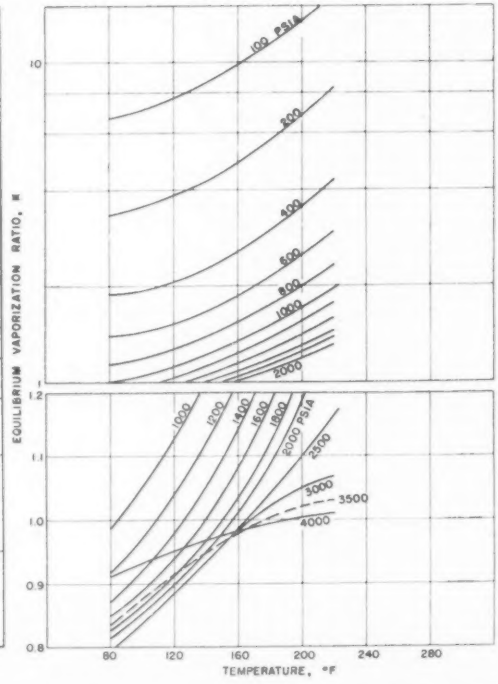


FIG. 15 — ETHANE K'S IN CRUDE OIL MIXTURE C-6 AS A FUNCTION OF TEMPERATURE AND PRESSURE.

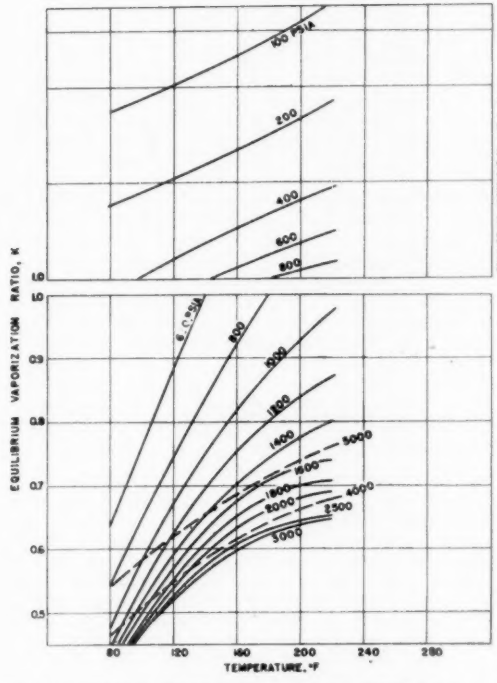


FIG. 16 — HYDROGEN SULFIDE K'S IN CRUDE OIL MIXTURE C-6 AS A FUNCTION OF TEMPERATURE AND PRESSURE.

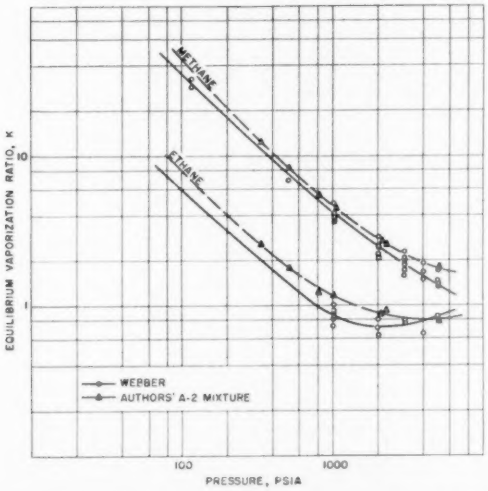


FIG. 17 — COMPARISON OF K'S IN ABSORBER OIL MIXTURE A-2 WITH WEBBER'S DATA AT 100°F.

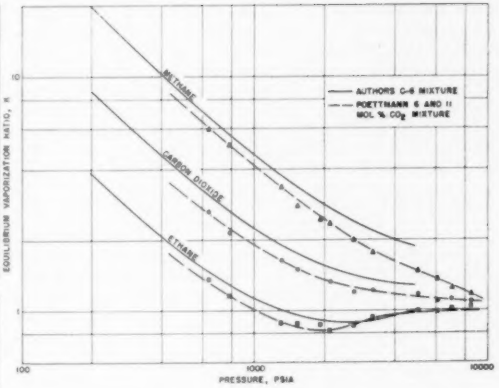


FIG. 18 — COMPARISON OF K'S IN CRUDE OIL MIXTURE C-6 WITH POETTMANN'S DATA AT 120°F.

position are evident but are mingled with pressure effects to the extent that it is difficult to make simple statements regarding the effect of composition on the K's of any component. For example, from Fig. 10 it may be seen that nitrogen K's at 1,000 psia in C-5 mixture are lower than those in C-6 at 80°F, higher from 94 to 182°F and lower again at 200°F. Fig. 11 compares the K values from the two absorber oil mixtures at 1,000 psia. The greatest numerical differences are in the non-hydrocarbon K's although the hydrocarbon K's show the qualitative composition effects described above.

The most interesting effect of temperature was the actual decrease in nitrogen K's with increasing temperature in certain temperature ranges. This was shown by no other components except methane over a very narrow range of temperature and pressure in the A-2 and C-6 mixtures. Such behavior of the nitrogen K's was not unexpected since other experimental data have shown the same.[1,2,3,7]

Comparisons of the data obtained by the authors with similar data in the literature are made in Figs. 17 and 18. In Fig. 17, methane and ethane K's from Webber's[8] data for absorber oil mixtures at 100°F are compared with data from A-2 mixture at 100°F. The scattering of Webber's data points is characteristic of data obtained from mixtures of varying overall composition. Poettmann's[9] data from a carbon dioxide-natural gas-crude oil mixture at 120°F are compared with C-6 data interpolated at 120°F in Fig. 18. The C-6 K's for methane, carbon dioxide and ethane are 10-30 per cent higher over the entire range of temperature and pressure. The difference may be attributed to the large difference in overall composition of the two mixtures. It is believed that the presence of nitrogen and hydrogen sulfide in C-6 mixture is less the cause of this than the large difference in the methane to heptanes-plus ratio between the two mixtures.

CONCLUSIONS

Equilibrium vaporization ratios were obtained for the non-hydrocarbons nitrogen, carbon dioxide, and hydrogen sulfide and for the hydrocarbons methane and ethane in two types of mixtures which are important in petroleum producing and

natural gasoline refining operations. Some effects of varying the overall mixture composition were obtained to serve as a guide in the application of these K values to other mixture compositions not specifically investigated. In making a choice as to which data to use it is recommended that overall compositions be matched as closely as practicable. It is believed that these data will apply with little error to mixtures having concentrations of the non-hydrocarbons within 5 mol per cent of those in the experimental mixtures.

ACKNOWLEDGMENT

The authors wish to express appreciation to the management of the Stanolind Oil and Gas Co. for permission to publish this paper; to J. B. Opfell for his assistance in designing and constructing equipment; to J. A. White who helped obtain the data; and to H. Thompson and L. Green for obtaining analyses.

REFERENCES

1. Boomer, E. H., Johnson, C. A., and Piercey, A. G. A.: "Equilibria in Two-Phase, Gas-Liquid Hydrocarbon Systems. II. Methane and Pentane," *Can. J. Research*, (1938) **16B**, 319.
2. Boomer, E. H., Johnson, C. A., and Piercey, A. G. A.: "Equilibria in Two-Phase, Gas-Liquid Hydrocarbon Systems. IV. Methane and Heptane," *Can. J. Research*, (1938) **16B**, 396.
3. Boomer, E. H., and Johnson, C. A.: "Equilibria in Two-Phase, Gas-Liquid Hydrocarbon Systems. III. Methane and Hexane," *Can. J. Research*, (1938) **16B**, 328.
4. Poettmann, F. H., and Katz, D. L.: "Carbon Dioxide in a Natural Gas-Condensate System," *Ind. Eng. Chem.*, (1946) **38**, 530.
5. Poettmann, F. H.: "Vaporization Characteristics of Carbon Dioxide in a Natural Gas-Crude Oil System," *Trans.* AIME, (1951) **192**, 141.
6. Eilerts, K., and Smith, R. V.: "Specific Volumes and Phase-Boundary Properties of Separator-Gas and Liquid-Hydrocarbon Mixtures," U. S. Bureau of Mines, R.I. 3642 (April, 1942).
7. Miller, P., and Dodge, B. F.: "The System Benzene-Nitrogen," *Ind. Eng. Chem.*, (1940) **32**, 434.
8. Webber, C. E.: "Equilibrium Constants for Hydrocarbons in Absorption Oil," *Trans.* AIME, (1941) **142**, 192.

DISCUSSION

By Fred H. Poettmann, Phillips Petroleum Co., Bartlesville, Okla., Member AIME

The authors of this paper are to be complimented for their thorough manner of studying the equilibrium vaporization ratios of the non-hydrocarbons which commonly occur in reservoir fluids. The data presented will go far in satisfying a long standing demand of the natural gasoline, refining and production phases of the oil industry for information on the vapor-liquid equilibrium conditions of these non-hydrocarbons.

The comments made here will be confined to the authors' carbon dioxide equilibrium vaporization ratios in the natural gas-crude oil systems. The following table shows the variation of methane and C_7+ composition on four reservoir fluid mixtures for which carbon dioxide K data have now been determined.

	Mole Per Cent Natural Gas Billings Crude	Natural Gas Erath Condensate	Jacoby-Rzasa C-5	Jacoby-Rzasa C-6
C_1	70 - 80	60 - 65	9.58	38.3
C_7+	8 - 10	25 - 26	68.7	41.2

The variation of the authors' carbon dioxide K values due to variation of the methane and C_7+ concentration is very small, almost negligible. As stated by the authors, the K data for carbon dioxide in the natural gas-crude oil system containing only 8-10 per cent C_7+ had carbon dioxide K's 10-30 per cent lower than the authors' K's in a system containing from 41.2 to 68.7 per cent C_7+. The authors failed to make one comparison, that of the carbon dioxide K's in a natural gas-condensate system. In the region removed from the convergence pressure, the authors' K's agree almost exactly with the K's in the natural gas-condensate system although the C_7+ concentration was only 25-26 per cent and the character of the C_7+ fraction was considerably different. Neglecting for a moment the character of the C_7+ fraction, it would seem that it takes a considerable variation in C_7+ concentration to cause only a minor variation in the carbon dioxide K values (C_7+ from 68.7 to 25 per cent with no change in K). On the other hand the agreement of the authors' carbon dioxide K's with those in the natural gas-condensate system may be purely coincidental, the effect of the C_7+ concentration on the K values being offset by the difference in character of the C_7+ fractions. ★ ★ ★

CORRELATION OF RADIOACTIVE LOGS OF THE LANSING AND KANSAS CITY GROUPS IN CENTRAL KANSAS

JOHN V. MORGAN, STANOLIND OIL AND GAS CO., TULSA, OKLA., JUNIOR MEMBER AIME

ABSTRACT

Although the Lansing-Kansas City groups constitute one of the more important producing horizons of Central Kansas, exploitation has been hindered by inability to consistently identify and correlate the various productive intervals. A study of gamma ray-neutron logs and core data indicates that definite zones exist which are related to production and which may be generally correlated over an appreciable portion of Central Kansas. A suggested system of zoning and nomenclature is developed and illustrated, along with examples of its specific application in overall evaluation and in development of zonal production characteristics. General adoption of the suggested system should aid appreciably in the future development of commercial Lansing-Kansas City production in Central Kansas. It is probable that similar systems might be developed for other regions where production is obtained from various uncorrelated and unnamed zones in thick pay intervals.

GENERALIZED GEOLOGY OF CENTRAL KANSAS

The most important large subsurface feature in Central Kansas regarding oil production is the Barton Arch, which is part of the Central Kansas uplift. The Barton Arch is a buried ridge of Pre-Cambrian granite running northwest-southeast, near which the majority of Central Kansas oil fields have been found. To the northeast of this arch, the granite dips sharply into the Salina Basin and similar basin areas to the west and south are termed the Hugoton Embayment and Anadarko Basin, respectively. This report deals primarily with the region of the Central Kansas Uplift and its southwestern flank. Fig. 1 indicates the general location of subsurface structural features along with the oil and gas fields of Central Kansas.

Above basal granite lies the Cambro-Ordovician Arbuckle Dolomite which is the principal oil producing zone in Central Kansas. This formation, as well as those higher in the section, reflects the general underlying granite structure; however, the Arbuckle top is an erosional surface and most oil producing structures are probably topographic hills. Formations above the Arbuckle in ascending order may include those of the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods as well as certain recent sediments. As the Barton Arch is approached, those formations below the Pennsylvanian and above the Arbuckle tend to pinch out until Pennsylvanian rocks, which include the Lansing-Kansas City groups, rest directly upon the Arbuckle. The Arbuckle itself is also completely eroded away at points on the Arch, but is up to 600 ft thick only 20 to 30 miles down dip.

Formations of the Pennsylvanian system vary considerably in thickness but probably average about 1,000 ft as an overall total. The more commonly known oil productive zones are the Tarkio, Topeka, Toronto (Dodge), Lansing-Kansas City and Marmaton. Of these, the Lansing-Kansas City, which varies from about 200 ft to 400 ft in thickness, is the most important, since its areal frequency of oil production is exceeded only by that of the Arbuckle.

Most Pennsylvanian rocks in Central Kansas were deposited in shallow seas which alternately covered, then retreated from the land. This resulted in recurring cycles of thin beds which cover relatively large areas. Small surface deformations during the period of deposition also caused variations in the type material deposited and its thickness. The local structures of Pennsylvanian time probably influenced the accumulation of

[1]References given at end of paper.

Manuscript received in the Petroleum Branch office Sept. 14, 1951. Paper presented at the Fall Meeting of the Petroleum Branch in Oklahoma City, Okla., Oct. 3-5, 1951.

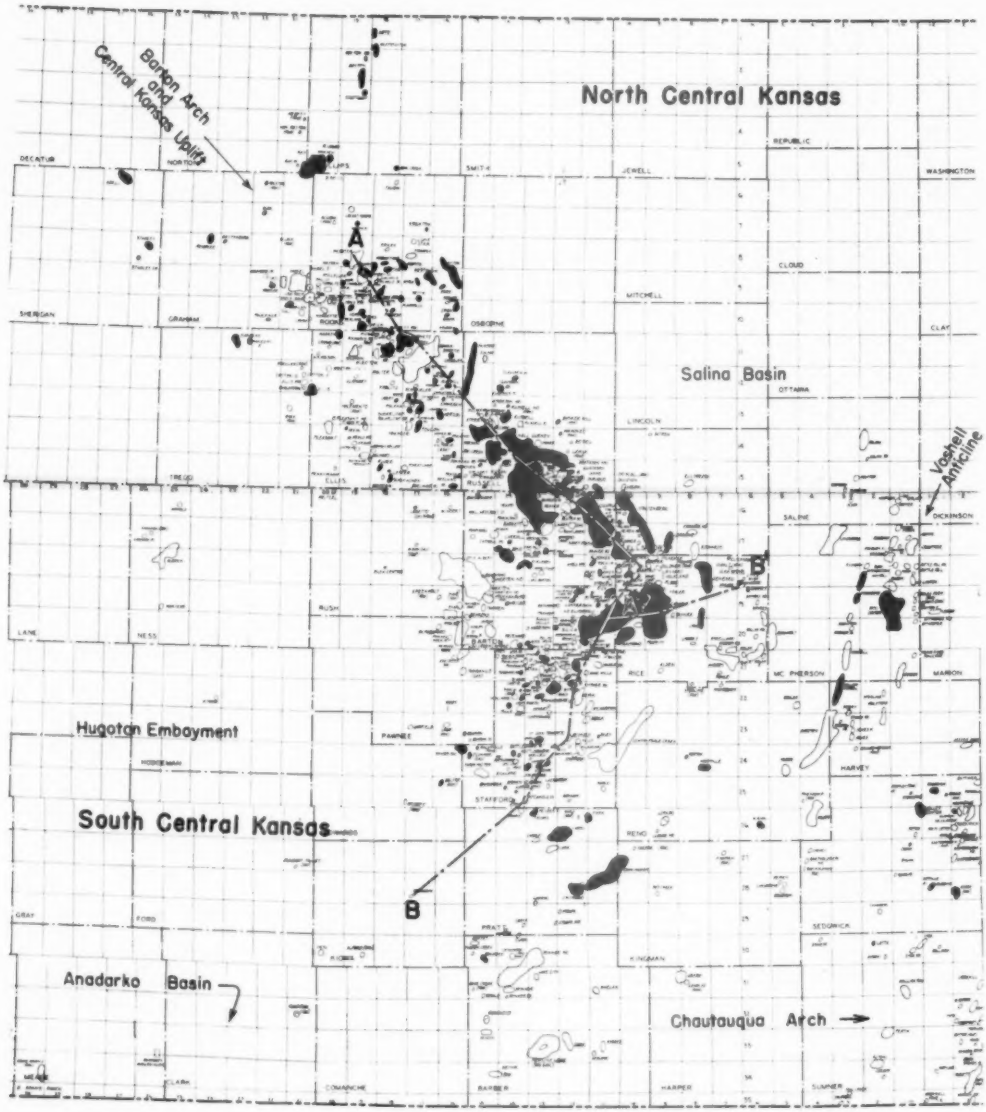


FIG. 1 — OIL AND GAS FIELDS OF CENTRAL KANSAS.

oil so that today our primary interest in these series is at points where maximum sedimentary variations may be expected.

THE LANSING-KANSAS CITY GROUPS

The Lansing-Kansas City groups are a series of limestones and shales over the majority of Central Kansas but shale intervals increase and sand members are observed near the Oklahoma border. These groups are exposed at the surface near the eastern border of Kansas but are found at depths of 3,000-4,000 ft in the central part of the state. Overlying formations, which are ordinarily easily identified by gamma ray-neutron logs include, in ascending order, the Iatan lime, Douglas shale, Toronto lime, and Heebner shale. The Heebner shale is a valuable marker since it is highly radioactive and produces large gamma ray curve deflections. The Heebner-Lansing interval decreases to the northwest on the Barton Arch until the Toronto lime immediately overlies the Lansing.

Oil production of the Lansing-Kansas City groups is found in porous streaks of various limes within the section. Identification and correlation of these limes by formational samples has not been generally possible over wide areas and identification on the basis of penetration from a Lansing-Kansas City top has been used in some localities. This method is not satisfactory due to the considerable variations in thickness of the lime and shale zones. It is also difficult to pick a uniform Lansing-Kansas City top from samples and drilling time since the "top" is usually a gradational change. Accurate lithological interpretation and identification of important zones can be performed by use of gamma ray-neutron logs.

Lithological Characteristics and Zoning of the Lansing-Kansas City Groups

Fig. 2 is the gamma ray-neutron log of one of the first wells in Kansas where the Lansing-Kansas City was diamond cored, and oil shows and lithology, as indicated by cores, are shown thereon. The correlation of limes and shales with the log is apparent. Identification of the various zones is necessary since only one or two zones will usually be found commercially productive in any field and changes in zonal thickness and lateral lithology may be important factors in the accumulation of oil. A standardized zonal nomenclature must also be used to permit accumulation of data regarding each zone's possible characteristics on a field or areal basis.

This and similar data at other wells prompted initial attempts to apply correct geologic names to the various Lansing-Kansas City intervals or zones. It was not found feasible to assign geologic names, as applied at Eastern Kansas outcrops and, therefore, letters have been used to define those arbitrary zones selected. The log of Fig. 2 is typical of recent good quality logs and shows all selected units or zones except zone M which, it was later discovered, is missing at this specific location. It is also speculative as to whether zone G' is present since this zone was not specifically observed until later at other locations.

The arbitrary zonal boundaries generally coincide with various gamma ray (shale) peaks which, of course, do not necessarily represent shale mid-points, nor top of a succeeding lime. It is advisable to examine the neutron curve to confirm shale interpretations and, at certain locations, the neutron curve must be used almost exclusively to determine the real, or apparent, zonal boundary. The foregoing method is believed the easiest approach for initially separating the various primary lime sequences which are of major importance. Since the shales are of little interest, the top of the included lime in each zone is the data that should be reported and analyzed on an individual well basis.

Correlation of Lansing-Kansas City Zones

The Lansing-Kansas City groups are sufficiently uniform in Central Kansas generally to allow correlation of the arbitrarily selected zones over an appreciable distance. Such correlation is presented on Fig. 3 where cross section AA' proceeds for a distance of about 100 miles northwest-southeast generally atop the Barton Arch, while cross section BB' is of a similar length but approximately at right angles to cross section AA'. Cross section BB' begins on the western flank of the Barton Arch, then proceeds up and over the Arch and into the Salina Basin. The specific location of these cross sections is shown on Fig. 1.

It should be noted that the indicated upper boundary line for zone A is above the true lithological or gamma ray-neutron Lansing-Kansas City top which would be near the mid-point

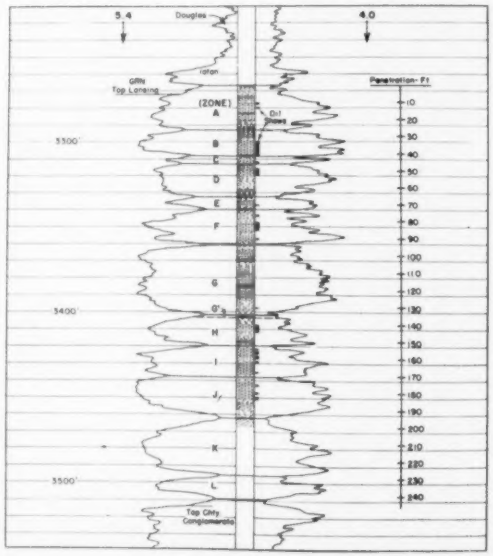


FIG. 2 — GAMMA RAY-NEUTRON LOG, STANOLIND E. SIEFKES "B" NO 11, SEC. 3-22S-12W, STAFFORD COUNTY, KANSAS.

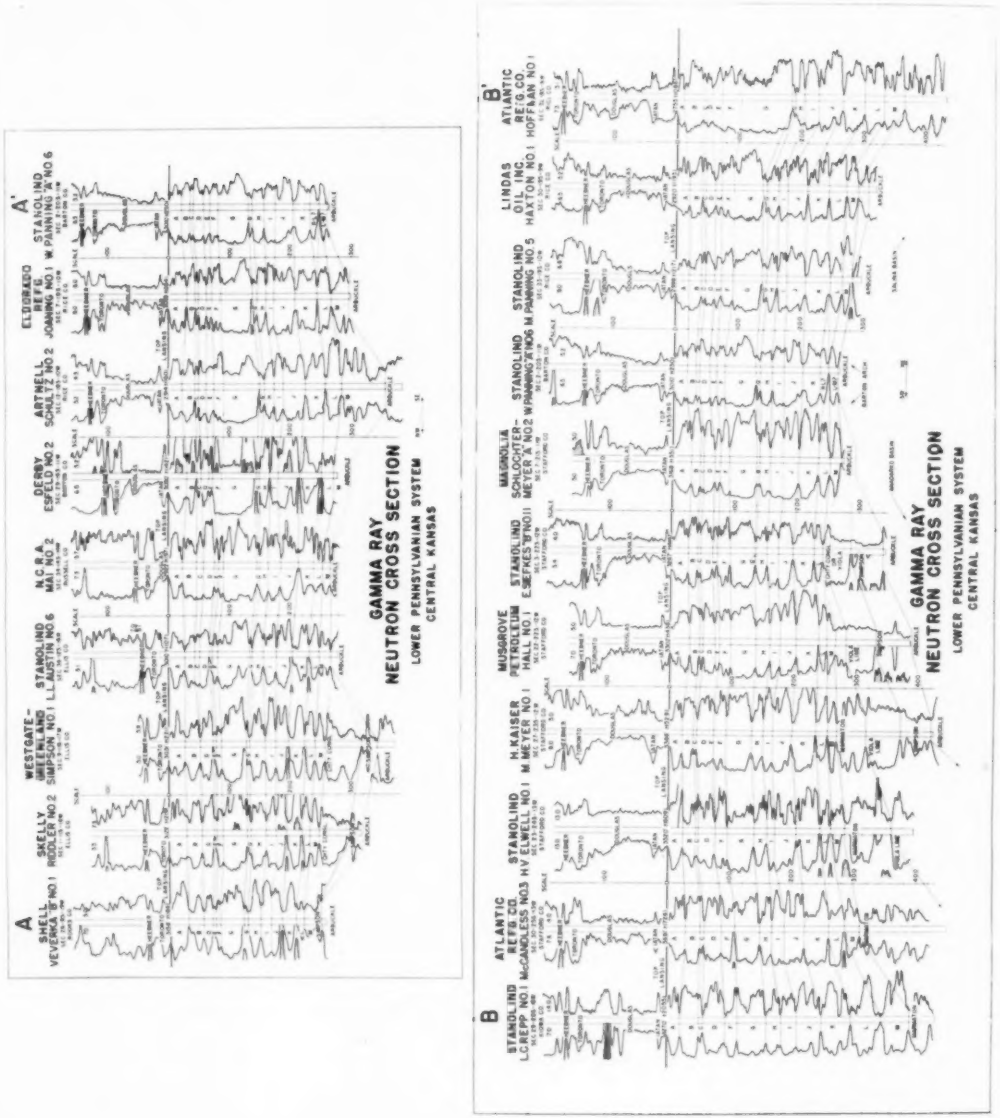


FIG. 3—GAMMA RAY-NEUTRON CROSS SECTIONS, LOWER PENNSYLVANIAN SYSTEM, CENTRAL KANSAS.

of the gamma ray curve shift. Also, the cross sections do not fully illustrate subsurface structure since logs are plotted flat on the Lansing-Kansas City top. Data show that cross section AA′ is relatively flat on the Lansing-Kansas City structurally with only 157 ft maximum variation in true subsea elevation while the Lansing-Kansas City top similarly varies almost 1,000 ft on cross section BB′.

Variations in zonal thickness are immediately apparent, and it is obvious that identification on the basis of penetration is impractical over any appreciable area. Also, some zones disappear in certain areas as does zone C on cross section AA′ and also zones E and G′ on cross section BB′. It has been further noted that the logs of wells in a single field will often show as much variation in certain zones as is indicated for them over the entire cross section AA′. Nevertheless, correlation of the selected zones is generally definite and consistent over the large area involved.

PRODUCING CHARACTERISTICS AND METHODS OF EVALUATION

The Lansing-Kansas City (LKC) is desirable to produce since it usually contains sweet crude with considerable volumes of gas. In no place has it been found to have a wholly effective water drive, and control is usually assumed to be completely volumetric even though recoveries in some cases approach 250 bbl per acre ft of net pay. Some limited water production is found (usually greater in zone G); however, it often appears to be relatively constant, or to decline in quantity along with the oil. The zones respond to acid treatment readily and should be treated during any test except in the event of good natural productivity. It is being gas driven at the Cunningham Field and water flood success is indicated in the more porous zones at certain accidental floods. Its erratic permeability development at many fields may prevent extensive future water flood programs although such programs should be considered.

It appears that formation sample analysis and drilling time correlation are not always sufficient for location of the probable productive zones. This arises from several factors, some of which are:

(1) Recent diamond cores have at times logged up to 40 separate oil shows over the LKC interval. In these wells many shows were of insignificant extent, but do illustrate that an oil show in samples could be carried practically all through the section.

(2) The upper portion (about 100 ft) often drills quite rapidly with rotary tools so that "breaks" are not observed. Also, certain dolomitic shales often break and drill at the rate of one-half min. per ft. When samples are poor these zones have been erroneously drill stem tested, as revealed by subsequent gamma ray-neutron (GRN) logs.

Cores, both diamond and conventional, are not the complete answer for accurate evaluation during initial rotary drilling. This arises since drill stem test of zones indicated to be oil bearing by cores have at times given only 10-30 ft mud with zero shut-in bottom hole pressure (BHP) recorded. It is not positively known whether this means that there is actually little or no pressure in the zone, or if an almost complete lack of inherent permeability prevents formational pressure from being recorded by the tool. It appears, however, that such lack of BHP indication has been regarded as positive condemnation by most operators, since no record could be found showing further tests of any such LKC zone.

Since the LKC is quite susceptible to acid treatment, the presence of low core permeability may not be serious if other factors are favorable. This is illustrated by a well which cored a very soft zone (K) that was oil bearing with 21.3 per cent average porosity but permeability was all less than .05 md. The log appeared favorable for this interval and, after 9,000 gal acid, the zone (8-ft thick) flowed 50 bbl oil per hour.

Lansing-Kansas City evaluation in a small area may often be made by use of gamma ray-neutron logs and diamond cores at certain wells, while drill stem tests with samples and drilling time in conjunction with logs are used at the remainder. This allows zones of oil saturation, as positively revealed by diamond core, to be checked by drill stem test at other nearby wells. Any drill stem test taken should allow 15 to 30 minutes for a closed in pressure reading since this may be as important data as actual fluid recovery.

It has been noticed that LKC structure, as revealed by its top, is usually not the primary factor controlling zonal productivity at any individual well. This structure generally reflects to some degree that of the underlying Arbuckle, although closure is normally not so extreme. Realizing the variations in zonal thickness which may occur within the LKC, it appears that the local structure of individual zones may not fully coincide with structure of the LKC top. It is therefore advisable to examine the structure of the lime zones of interest, along with the LKC top, in any field where such is possible.

It is probable that local or areal changes in lateral lithology within any zone were a factor in the accumulation of oil. It has been noted that porous zones in the limes as shown by GRN sometimes tend to become somewhat shale filled at other locations. In the presence of some slight regional or local dip these conditions would appear to fulfill those of a stratigraphic trap.

The cross sections of Fig. 3 show that shale breaks between certain zones, particularly those above G, tend to be somewhat erratic in occurrence. Concurrently with this, thick porous limes are usually present in the overall interval and such are often oil productive if other conditions are favorable. The occurrence of zonal thickening and/or absence of correlatable shale breaks should therefore be regarded as favorable for localized zonal productivity.

Characteristics of Individual Zones

It has been found that certain zonal characteristics may be observed by examining well and log data where positive Lansing-Kansas City tests have been made. A positive test is deemed to be the actual production test of a zone, a definite drill stem test, or positive fill-up when the zone was penetrated with cable tools. Lack of electric or GRN logs at many wells makes their inclusion impracticable; however, in fields where relatively uniform thickness of all zones is indicated, the producing zone (A through M) may at times be selected by correlation with logs of nearby wells.

The statistical results of a study of this type, which included 471 positive tests at 174 wells, are shown on Fig. 4, with division made for North Central and South Central Kansas as indicated by Fig. 1. When viewed in regard to the total area involved, the number of tests analyzed is obviously quite low and indicated characteristics should be regarded as preliminary in nature. The use of standardized zonal nomenclature

by all operators should allow any inherent zonal characteristics to be further observed and interpreted.

It is emphasized that the percentages of success indicated for the various zones do not mean that such commercially productive frequency can be expected in every field or well. Obviously the major portion of the tests to which the percentage success figures each apply would not have been made if all factors available for analysis had not indicated good chances for success. Even after all possible prior analysis, the overall success frequencies are quite low and it is hoped that use of zonal nomenclature will ultimately allow improvement in this respect.

It is noted that over 3½ times more tests are shown for North Central Kansas than for the South Central portion. It is probable that this total number of tests is a function of the frequency of oil of occurrence with North Central Kansas being the more favorable area. This is not wholly true, however, since LKC production off the Barton Arch has sometimes been disregarded in the past. The upper zones are indicated generally the most favorable in North Central Kansas where they are somewhat difficult to correlate, while the lower zones are generally better in the South Central part. The lower zones have also produced considerable oil in the northern area.

Zone A is the uppermost zone and commonly shows a gradational upper contact with lime gradually replacing shale as the zone is penetrated. It is normally productive only in Russell County and immediately adjacent areas, although one well was noted in Zone A at Chindberg Field of McPherson County. Porous intervals in the lime are usually about four to six ft in thickness and many logs show one porous interval near the top and one at the bottom of the zone.

Zone B is primarily productive in the general vicinity of Russell, Rooks and Phillips Counties where it is called the 30-ft zone and usually attains its maximum thickness. More tests are recorded in this zone than for any other in North Central Kansas and the 85 per cent success frequency is one of the highest shown. Production from B in South Central Kansas is believed less likely, but, when such is found, recoveries are good, as at Cunningham Field in Pratt County where B is probably the producing zone. No wells from Cunningham Field were included in the present statistical study.

Zone C is a very thin unit originally selected primarily for aid in correlation. It is usually readily correlated off the Barton Arch and at many places on the Arch; however, its presence is not apparent north of Ellis County. In Russell and Ellis counties, it often tends to merge with zone B as the separating shale break becomes less distinct. It is highly productive in this locality and has the highest success frequency of any zone in North Central Kansas. Zones B and C are good examples of production being obtained from an interval which has thickened or where shale breaks tend to disappear.

Zone D like other upper zones is good in North Central Kansas, and at times its upper portion tends to merge with zone C. It is probably the equivalent at most places of the so-termed 60-ft zone and also has a very high success frequency in South Central Kansas, where it is probably the best upper zone. It tends to produce more gas than any other upper zones.

Zone E was originally named primarily for correlation purposes, as it rarely attains sufficient thickness to be commercially productive even if oil bearing. Zone F is of near equal significance in both areas since it has generally given good recoveries. It tends to disappear or become part of G at some locations when the intervening shale break is not distinct. Like D, it is usually somewhat more gas productive than other upper zones.

Zone G is the thickest lime sequence selected for correlation and is usually the one most readily identified in preliminary correlation work. It is often characterized by a weathered chert section at the top and porosity-permeability conditions are generally good. It has given good recoveries at certain locations in both areas, but available data show no successful tests south of Barton County. Initial productivities are usually high and it normally has a considerable amount of water present.

Production from G is usually obtained in the upper portion or probable 90-ft zone and oil is not commonly produced from the lower part unless a localized shale streak develops such as shown on the log of Stanolind's L. L. Austin No. 6. This lower part may then be termed the 120-ft zone in Russell County, but it has no readily observed counterpart in other areas. The thickness and good porosity-permeability of G indicate it to be the most feasible zone for salt water disposal usage in the Lansing-Kansas City.

Zone G′ is a very small zone which was discovered correlatable after having selected the zonal letters on the Siefkes "B" No. 11 log. It has no production at any place and serves only to make interpretation of zone H more difficult. This arises since where G′ is not obviously present, a slight neutron curve reversal in the top on Zone H may be a shale tendency rather than porosity. Of course, if this shale is of any extent it should be revealed by the gamma ray; however, on old logs this is not always the case.

Zone H is one of the most disappointing zones since it nearly always has favorable log characteristics and oil saturation is not infrequently encountered. Unfortunately, tests of this zone often produce water only and zero BHP is also apparently common. The shale tendency due to G′ as discussed above has also been an unfavorable factor; nevertheless, recoveries of 70,000-80,000 bbl of oil per well may be had in the event the zone is productive.

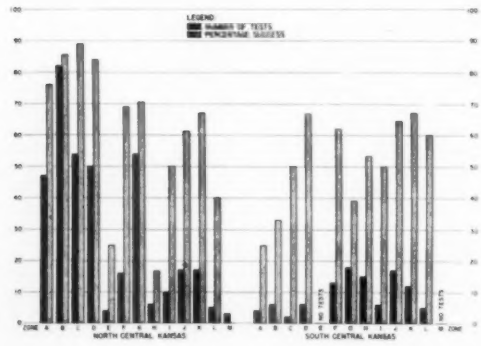


FIG. 4 — GRAPHICAL SUMMARY OF LANSING-KANSAS CITY TESTS.

Zone I is an average zone with 50 per cent success frequency but oil occurrence is apparently somewhat rare since number of total tests is quite low. Porosity of a high degree is not often indicated and little consideration is indicated for I unless it can be correlated with offset production.

Zone J is one of the most favorable zones in the Lansing-Kansas City and gives excellent recoveries when productive. The GRN log usually shows a large porous interval in this zone, however, due to its depth within the LKC, zone J has probably been often overlooked in the past, even though it has produced over 100,000 bbl per well in certain instances.

Zone K has probably also been overlooked at times in the past but it does have a very high success percentage in both areas and is usually quite commercial when productive. Very few tests have been made in zone L and it is assumed that oil occurrence is infrequent since only moderate success has been obtained when it was tested. No ultimately successful tests were found for zone M but it is noted that the zone pinches out at places and, for example, it is not present on cross section BB' at the E. Siefkes "B" No. 11 log.

CONCLUSIONS

1. The Lansing-Kansas City groups can be zoned and correlated in most of Central Kansas by use of gamma ray-neutron logs.

2. Identification of the various zones will permit correlation of test results and should increase the possibility of obtaining commercial production.

3. A standardized nomenclature among the various operators will permit accumulation of experience and information regarding possibilities of the various intervals and help in exploitation of the section.

4. The technique of zonation and correlation on the basis of gamma ray-neutron logs should be helpful in exploitation of other producing horizons where pay is scattered throughout a thick, generally undifferentiated interval.

ACKNOWLEDGMENTS

Acknowledgment is made to Stanolind Oil and Gas Co. for permission to publish this material and to various Stanolind engineering and geological personnel for their suggestions.

REFERENCES

Portions of the below listed publications were helpful in developing background material on the general geologic conditions of Central Kansas. The publication by VerWiebe also provided the primary data for showing Central Kansas fields which have Lansing-Kansas City production.

1. Moore, Raymond C.: "Divisions of the Pennsylvanian System in Kansas," State Geol. Survey of Kansas, *Bulletin 83*, (1949).
2. Moore, Raymond C., Frye, John C., and Jewett, John Mark: "Tabular Description of Outcropping Rocks in Kansas," State Geol. Survey of Kansas, *Bulletin 52*, (1944).
3. Lee, Wallace, Leatherock, Constance, and Botinelly, Theodore: "The Stratigraphy and Structural Development of the Salina Basin of Kansas," State Geol. Survey of Kansas, *Bulletin 74*, (1948).
4. VerWiebe, W. A., *et al*: "Oil and Gas Developments in Kansas During 1949," State Geol. Survey of Kansas, *Bulletin 87*, (1950).

DISCUSSION

By Kenneth L. Smith, Champlin Refining Co., Enid, Okla., Member AIME

Morgan is to be complimented upon his system of zoning and nomenclature as it has been developed. He has shown the logic and feasibility of such a correlation which should be a most valuable aid to the oil operator in Central Kansas. This study should be expanded further to show how it can be applied to other types of logs in the same area.

The prime objective of this paper is the correlation of the various productive zones in the Lansing-Kansas City groups throughout Central Kansas by a study and comparison of gamma ray-neutron logs and core data. The identification of these zones by alphabetical nomenclature appears to be an excellent method for identifying the various members of the Lansing-Kansas City groups which are often found to be productive in the Central Kansas areas outlined in Fig. 1 of this paper. As pointed out, the presently used method of identifying these zones by depth from the top of the Lansing has led to considerable misunderstanding due to the change in thickness of the zones. If the oil operator in this section of Kansas is provided with a means to correlate accurately, not only the productive Lansing-Kansas City zones within the same field, but from one field to another it should be a considerable aid in the efficient exploitation of the Lansing-Kansas City production.

The various productive zones in the Lansing-Kansas City have been designated from A through M, with a zone G' shown on a considerable number of logs in Fig. 3. On most of the logs it appears that the zone G' could very easily be incorporated into the zone H, which would tend to simplify the method of zoning. It is stated in the paper that G' is a very small zone with no record of individual production; therefore, elimination of this additional breakdown, and placing it into zone H should tend to simplify the classification procedure. No mention is made as to whether zone G' could be the top of the Kansas City group; if this is the case, it could account for the irregularities in this portion on most of the logs presented.

Fig. 4 of this paper graphically illustrates the percentage of success for the completion of oil in all zones A through M. It is doubtful if this information is of sufficient accuracy to make such a tabulation for each individual zone. This would be particularly true for those tests which were made by perforating casing after it has been set through any group of particular zones. Field experience has shown that the cement bond behind casing is very poor throughout the Lansing-Kansas City section whenever there are oil shows present and it is not unusual to encounter communication between zones which might be 40 to 50 ft removed from the zone being tested. The possibility of communication up and down the well bore is almost assured if the well is acidized through

the perforations. With the previous facts in mind, it is suggested that Fig. 4 should only be used as a relative guide as to what group of zones have experienced the highest percentage of success.

It is suggested to the industry to use the nomenclature of the Lansing-Kansas City zones as set forth in this paper and that some type of study group be organized in an attempt to collect all available data from operators throughout the Central Kansas area. This should include the following: number of attempted completions, percentage of success, initial production, estimated recoverable oil per acre, type of reservoir control, and any other pertinent data which might be useful. If these data are collected, properly assembled and correlated, it is probable that the percentage of success in the Lansing-Kansas City completion attempts would be increased. Further, such a study might evolve certain prerequisite characteristics on the gamma ray-neutron logs before any particular zone could carry oil in commercial quanitites. If this study does not refine itself to such a point, it might at least show what zones in any particular area would have the best chance for a successful completion, provided that their logs meet certain qualifications. ★ ★ ★

The Drift of Things

. . . as followed by **EDWARD H. ROBIE**
Secretary AIME

In many ways, the Annual Meeting of the Institute in February was the most successful yet held. Attendance surpassed even that of the 75th Anniversary Meeting in 1947 with its international flavor. The number of technical sessions and the number and quality of papers presented almost certainly set a new record. The banquet was the best attended of any yet held even though the price reached a new high. Despite the demand for almost 1,700 tickets to the banquet, some felt that the price — $13.50 — was higher than they could afford.

There are two points of view: one is that this is the big social event of the year for mining men and that is is worth from three to five dollars more to have it at the Waldorf and to have a luxury menu, as we did this year, with turtle soup, a fish course, guinea hen for the entree, and wild rice (which we understand is $3.50 a pound) for a vegetable. The other point of view is that a seven or eight dollar banquet of more simple food at the Commodore Hotel would more than make up in appeal especially to the younger and less well-heeled members, what it would lack in glamor.

Though meeting rooms were not entirely adequate for all of the technical sessions this year, the idea of transferring the meeting to Atlantic City, with more commodious quarters, got no support whatever. The feeling of Western members seems to be that if we come East then let's go to New York and not to a summer resort in the winter time.

Petroleum Branch Affairs

. . . as interpreted by **JOE B. ALFORD**
Executive Secretary, Petroleum Branch

This will initiate a column designed to keep you informed on the activities of the Petroleum Branch and the decisions of your executive and other committees. It will appear monthly when desirable, usually in connection with Edward H. Robie's column, "The Drift of Things"; it will be written by members of the Branch staff. At times it will interpret for you certain changes in Institute bylaws and procedures, and will discuss various phases of Institute business of interest to members.

Establishment of a Petroleum Section and Chapter Conference

As many of you will remember, the rapid development of petroleum engineering during the thirties brought a somewhat similar development in the Petroleum Division of AIME as the professional society for petroleum engineering. This growth was arrested during World War II, but it had good prospects of continuing after the war and a headquarters office for the Petroleum Division (changed to Branch in 1948) was established in Dallas in early 1946 to serve it. The primary function of this office was to serve the professional and technical interests of the membership through the handling of meetings and publications. It had only nominal administrative or political functions.

The office has continued in this capacity since 1946, but during this time nine (of the current 15) new Local Sections, Chapters, and Sub-Sections have been founded. Thus, the administrative and political organization of the Branch has been formed in this period. The tie between these petroleum units and the Branch office has grown steadily closer, but the office has continued to serve only their professional functions, while their administration has been handled largely by the Institute headquarters in New York. This by-passing of the Branch on administrative and political matters has caused some confusion because the officers of the Sections and the Branch have sometimes been uninformed on the actions and wishes of each other.

To help improve this situation, the Branch Executive Committee voted in New York to establish what will be known as the Petroleum Branch Section and Chapter Conference. It is anticipated that this conference will function like the Council of Section Delegates functions for the Institute — it will simply be a Section delegate's council at the Branch level. The conference will meet at the Petroleum Branch Fall meeting each October, and all Sections, Chapters, and Sub-sections will be invited to send a delegate to it. At the first meeting, to be held during the 1952 Fall Meeting in Houston in October, the conference will elect its own officers and establish itself as a continuing organization. The conference will meet with the Branch officers, to discuss Local Section and Petroleum Branch business, then possibly in closed session, and may submit resolutions to the Branch Executive Committee.

The Conference will bring about a closer liaison between the local units and the Branch, and will result in a better functioning organization. Also, it will be a channel through which individual members can (and should) present suggestions or complaints on Branch and Institute affairs to the Branch Executive Committee. You are urged to present your ideas through this channel, as the collective voice of the membership is the foundation upon which the society functions.

Petroleum Branch Fall Meetings

HOUSTON, RICE HOTEL, OCTOBER 1, 2, 3

LOS ANGELES, STATLER HOTEL, OCTOBER 23, 24

Elsewhere in this issue is a detailed story on these meetings. Within the next few weeks a card will be mailed to all Petroleum Branch members on which hotel reservations can be made for the Houston meeting. We are guessing that the attendance at Houston will be about 1,200, and although we anticipate having plenty of hotel space, your reservations should be made as soon as possible. ★ ★ ★

Morgan J. Davis Heads Petroleum Geologists

Morgan J. Davis, vice-president and director in charge of exploration, Humble Oil and Refining Co., Houston, Tex., became the 36th president of the American Association of Petroleum Geologists on March 27, it has been announced by Frank A. Morgan, past-president of the association. Other AAPG officers elected to serve during 1952-53 include John G. Bartram, consulting geologist, Stanolind Oil and Gas Co., Tulsa, Okla., vice-president; Robert H. Dott, director, Oklahoma Geological Survey, Norman, re-elected secretary-treasurer; and Kenneth K. Landes, department of geology, University of Michigan, Ann Arbor, re-elected as editor of the AAPG monthly *Bulletin*.

President Davis brings to his AAPG office a wealth of experience acquired during his rise from field geologist to his present position. Upon graduation from the University of Texas in 1925, he joined the geological department of Humble and was assigned to reconnaissance and detailed structural mapping near Cisco, Tex., and later in eastern New Mexico. From 1929 to 1934, he worked in the Dutch East Indies for Ned. Koloniale Petr. Mij. Since 1934, he has been with Humble in Houston. ★ ★ ★

Scholarship Established Honoring E. L. Drake

A college scholarship fund in honor of Edwin L. Drake, who drilled the world's first commercial oil well in 1859 near Titusville, Pa., has been set up at the Pennsylvania State College, State College, Pa.

The Penn State board of trustees has accepted from John P. Herrick of Olean, N. Y., oil man and author, a gift of securities having a market value of $27,500 to endow the perpetual scholarship fund. Interest from the fund will finance two scholarships to begin next fall. Candidates will be ambitious high school graduates aiming at an oil industry career in petroleum geology, mineralogy, or engineering.

One scholarship will go to a resident of Pennsylvania and another to a nonresident in amounts covering annual fees charged each group. A third scholarship will become available later from the endowment. All will be administered by the committee on scholarships and awards of the Penn State School of Mineral Industries. ★ ★ ★

Address Change Procedure

If either your address or position changes you owe it to yourself and friends to let AIME headquarters know a month before the change is made or as soon as possible if you can give your future address accurately. Please following these suggestions:

1. Give your name and the address to which publications and correspondence should be sent. Mark this: "Publications address."

2. Give your name, title, or company position, and your address the way you want it to appear in the next Directory. Mark this: "Directory listing."

3. A short personal item for publication in the monthly journal will be appreciated.

Send your advice, by postal card or letter, to: AIME, 29 W. 39th St., New York 18, N. Y.

Air Pollution Symposium Planned for May 5-6

The second National Air Pollution Symposium will be held May 5 and 6 at the Huntington Hotel, Pasadena, Calif. The meeting is expected to attract several hundred scientists, engineers, technical workers and executives interested in phases of air pollution affecting industrial communities.

Under the sponsorship of Stanford Research Institute, in cooperation with California Institute of Technology, the University of California at Los Angeles, and the University of Southern California, sessions will follow the general pattern of the first symposium held under the same auspices in 1949.

A. M. Zarem, chairman of the executive committee, said that the program will cover general topics of new techniques in sampling, analysis and instrumentation, fundamental chemistry and physics of the atmosphere, the contribution of internal combustion engines and biological aspects of atmospheric contamination. ★ ★ ★

1955 Meeting in Chicago

An invitation to hold the Annual Meeting in Chicago in 1955 has been accepted by the Board of Directors. Unless otherwise determined by the Board, the dates will be Feb. 14-17. Chicago will also be the scene of the Fall Meeting of the Institute this year, on Sept. 5 and 6, in connection with the Centennial of Engineering celebration. ★ ★ ★

Slogan Adopted For Engineering Centennial

In a move to awaken the public to the prominent part the engineering profession has played in bringing America to its present high economic and social levels, the Centennial of Engineering, to be celebrated in Chicago this year, will build all of its activities around the slogan, "Human Well-being Through Engineered Progress."

Thinking behind the slogan was voiced by Karl T. Compton, chairman of Massachusetts Institute of Technology. He said:

"There is surely a close relationship between the work of engineers and the high standard of living arising from the high per capita production in the United States. In no other country is this profession of such high standing. Furthermore, the demand for engineers continually exceeds the supply, because our free enterprise system gives almost limitless opportunity and very great incentive to make things new and to do things better."

The centennial slogan will be featured by leading industries during 1952 in advertising and special books and movies being prepared for distribution to schools and colleges of the country. ★ ★ ★

Lane-Wells Company Marks 20th Year

Lane-Wells, oil field service company headquartered in Los Angeles, celebrated its 20th birthday March 19, 1952. Born in the depression, the company pioneered gun perforating as an oil field service.

From its introduction gun perforating was rapidly accepted by oil well operators because it enabled them to reactivate old wells and permitted more economical and efficient completion methods in new wells. Lane-Wells has completed more than 165,000 gun perforating jobs and more than 40,000 radioactivity well logs. ★ ★ ★

Industrial Research Conference

The third Annual Conference on Industrial Research will be held at Columbia University June 9-13, 1952. The Conference, under the sponsorship of the Columbia Center for Studies of Research Administration, has as its theme "The Design of Research Operations." Program topics will include the design of research facilities, research projects, programs, design of experiments, and operations research. Inquiries should be addressed to Prof. David B. Hertz, 409 Engineering Bldg., Columbia University, New York 27.

Personals

DELMAR H. LARSEN, formerly with Baroid Sales Division, National Lead Co., has opened offices in Los Angeles as a consulting chemical and petroleum engineer and patent agent. He was with Baroid for 15 years, until that firm moved to Texas, and was director of research and more recently manager of the patent department.

+

A. P. CLAUDET, formerly general manager and executive vice-president of Schlumberger Surenco and Schlumberger of Latin America, has become a partner of the new firm of Bowling and Claudet in New Orleans, La. Claudet is a graduate of the Ecole Professional Diderot, Paris, France. He was connected with the Schlumberger group for more than 22 years and is a past president of the New Orleans Geological Society.

+

CLARK F. BARB, head of the petroleum engineering department at the Colorado School of Mines, has been named chairman of the Colorado State Secondary Recovery committee of the Interstate Oil Compact Commission.

+

W. DONALD QUIGLEY is now working as a consulting geologist in the Rocky Mountains area in the field of petroleum and mineral deposits.

+

LEE J. THRONSON has become production manager of Mendota Oil Co., Fort Worth, Tex. After graduation from the University of Minnesota School of Mines in 1938, Thronson joined Sun Oil Co., with whom he worked in various parts of Texas until March of this year. Since November, 1951, he had been area superintendent at Premont, Tex. During World War II he served in the U. S. Army Corps of Engineers in Africa, Italy, France and Germany, attaining the rank of captain. He was 1951 chairman of the Southwest Texas Section of AIME.

W. B. RUMMELL has resigned as reservoir engineer with Continental Oil Co., Ponca City, Okla. He has accepted a position with the John P. Gaty Oil Co., Wichita, Kans., as production engineer.

+

JOHN W. RHEA, JR., is now with the Southeastern Drilling Co., Dallas.

+

ROBERT P. MANGOLD has been made manager of operations for the D. K. Partnerships, Bakersfield, Calif.

WILLARD ARDELL SCHAEFFER, JR., is now consulting petroleum engineer for the Southern Production Co., Inc., Fort Worth.

+

ROBERT W. ZWICKY, junior exploitation engineer, Shell Oil Co., Corpus Christi, Tex., is now at Calgary, Alberta.

+

MYRON A. WRIGHT has joined the International Petroleum Co., Ltd., Coral Gables, Fla.

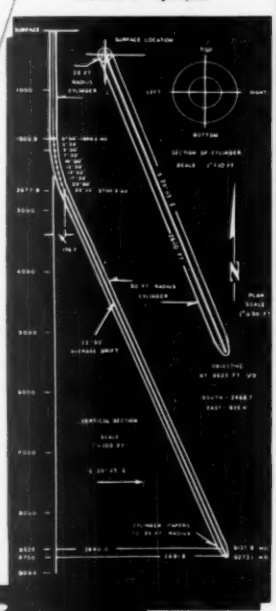
Specialized Engineering Services...

Eastman will assist you in planning your drilling program

Available on Directional Drilling Projects

Eastman is highly qualified to give the oil field operator specialized engineering and consultation service on his CONTROLLED DIRECTIONAL DRILLING PROBLEMS in every major oil field throughout the world. Eastman's Engineering, research, and experimental departments have had many years of experience in the fields of Controlled Directional Drilling and Oil Well Surveying. These Engineers will make planned proposals, plot survey records, estimate costs, design special tools, or compile specific data and records on Directional Drilling work wherever possible, as desired by the operator. These services save expensive changes and alterations in his plans later on.

Directional Drilling Proposal



Call an Eastman Engineer: He's ready to serve you ...TODAY!

Eastman
OIL WELL SURVEY COMPANY
LONG BEACH • DENVER • HOUSTON

Export Sales & Service: EASTMAN INTERNATIONAL COMPANY • P.O. Box 1500 • Denver, Colorado

Employment Notices

The JOURNAL will post notices of men and jobs available. Companies and AIME members are invited to use this space, for which there is no charge. Except as noted below, address replies to: Code (appropriate number), JOURNAL OF PETROLEUM TECHNOLOGY, 408 Trinity Universal Bldg., Dallas 1. Show return address on envelope. These replies will be forwarded unopened and no fees are involved.

Replies to the positions coded Y6653, Y6539, Y5908, Y5858, Y5531 and Y5532 below should be addressed to: Engineering Societies Personnel Service, 8 West 40th St., New York 18, N. Y. The ESPS, on whose behalf these notices are published here, collects a fee from applicants actually placed.

PERSONNEL

♦ Reservoir engineer, ten years' experience with major oil company in United States and Venezuela, desires position either domestic or foreign. Broad experience in reservoir engineering, pressure maintenance, secondary recovery and well completions. Familiar with oil field geology. Excellent references. Age 31, married. Available for interview. Code 161.

♦ Petroleum engineer, 24, married, graduate with three years' experience with reliable company including production and reservoir engineering. Can furnish good recommendations. Desires position with progressive independent or small company. Code 162.

POSITIONS

♦ Small expanding oil and gas company currently operating in the San Juan Basin, New Mexico, has need of a petroleum engineer with drilling rig and gas production experience. Will head department. Age 28 to 35. Salary commensurate with ability. Reply giving educational background and experience. Code 539.

♦ Petroleum geologists, experienced, for subsurface study. Should have three to five years' experience in geological work. Location, Texas. Y6653.

♦ Engineering draftsman with experience, to detail and lay out piping and equipment for oil terminals. Salary, $4,800 a year. Y6569 (a).

♦ Engineers. (a) Oil refinery process design engineer, 30-40, chemical or mechanical engineering graduate, with actual oil refinery distillation process design work on cracking plants or equivalent. Will supervise engineers and draftsmen in the design of all types of distillation units from flow plans and data. Must be able to discuss with oil refinery expert all phases of oil refinery design. Salary open. (b) Oil refinery field maintenance and construction superintendent, 30-60, with actual experience in the field working for an oil company or for a contractor who has contract work in an oil refinery performing the work listed as follows: Hiring and supervising all classes of mechanics and assigning them to oil refinery maintenance or construction as required. Salary open. Locations, New York Metropolitan area or Gulf Coast area, or both. Y5908.

♦ Project engineer with knowledge of design, layout, mechanisms and material specifications for lube oil furfural solvent extraction, MEK solvent dewaxing and propane de-asphalting units. Should have ability to follow the detailed design, layout and drawings through the engineering department. Salary commensurate with experience, including profit-sharing bonus. Location, Ohio. Y5858.

♦ Engineers. (a) Equipment and cost engineer, about 30, with petroleum engineering degree and about five years' experience. (b) Production engineer — petroleum, 25-40, with about four years' experience. (c) Drilling engineer, 25-35, with degree in petroleum engineering and about three years' experience. Location, Colombia, S. A. Y5531.

♦ Engineers. (a) Petroleum engineer for field operations, 25-35, with degree in petroleum engineering or equivalent and about three to five years' experience. (c) Division safety supervisor, 30-45, graduate, preferably mechanical, with five years' experience in petroleum, drilling and production safety supervision. (d) Junior engineers, recent petroleum engineering graduates, capable of developing under training. Location, Peru, S. A. Y5532. ★ ★ ★

Proposed for Membership, Petroleum Branch

Total AIME membership on Feb. 29, 1952, was 17,221; in addition, 2,341 Student Associates were enrolled.

ADMISSIONS COMMITTEE

T. D. Jones, chairman; Thomas G. Moore, vice-chairman; H. S. Bell, F. W. Hanson, R. H. Chadwick, T. W. Nelson, C. A. R. Lambly, John T. Sherman, A. C. Brinker, G. P. Lutjen, Ivan Given, E. A. Prentis, C. Leslie Rice and J. H. Scaff.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend privileges, but does not desire to admit persons unless they are qualified. Objections on applications should be received on the 15th of the month following publication of PETROLEUM TECHNOLOGY.

In the following list C/S means change of status; R, reinstatement; M, member; J, Junior Member; A, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ARKANSAS

El Dorado — Whitney, J. W. W., Jr. (R,C/S-S-J).

CALIFORNIA

Albany — Strong, William R. (C/S-S-J).
Baldwin Park — Hayward, David K. (J).
Long Beach — Wilson, Richard A. (C/S-S-J).
Sacramento — Moore, Return F. (J).
Rangely — Thornton, James T. (C/S-J-M).

ILLINOIS

Crystal Lake — Vagtborg, Harold, Jr. (C/S-S-J).
Mt. Carmel — Crane, John K. (J).

LOUISIANA

New Orleans — King, Willie E. (C/S-S-J).
Shreveport — Forgotson, James Morris (J).

MICHIGAN

Roscommon — Ellison, Raymond H. (J).

MISSISSIPPI

Washington — Newsome, Joseph R. (J).

NEW MEXICO

Monument — McBryde, Oliver C., Jr. (C/S-S-J).

NEW YORK

New York — Ogden, Clarence B. (M).

OKLAHOMA

Edmond — Caldwell, Robert Harrison (J).
Oklahoma City — Caywood, Robert M. (C/S-J-M); Holman, Harvey H. (C/S-J-M); Maples, Steve Campbell, Jr. (C/S-A-M); McLain, Mason W. (J); Waterman, Chester B. (J).
Sapulpa — Ammann, Charles B. (J).
Seminole — Hamilton, James C. (C/S-A-M).
Tulsa — Fuerst, Edward M. (J); Louy, Frank A., Jr. (M); May, Russell D. (M); Riley, Homer G. (A).

PENNSYLVANIA

Pittsburgh — McCain, H. M. (M).
State College — Jones-Parrah, Juan (J); Killins, Charles R. (J).

TEXAS

Abilene — Young, William P., Jr. (J).
Alvin — Dommesnares, Orland R. (C/S-S-J).
Bellaire — Hinds, Richard F. (M).
Bishop — Harlan, William T. (J).
Brownfield — Pearman, Benjamin R. (C/S-S-J).
Corpus Christi — Wheless, Chester L. (C/S-A-M).
Fort Worth — Harris, Sidon (M); Laflin, George P. (A); Moran, Frank W., Jr. (R, C/S-S-J).
Garden City — Tuffly, Harry J. (J).
Grand Prairie — Sandberg, C. Roger (M).
Houston — Horvitz, Leo (M); LeGrand, William H. (R,C/S-S-M); Sedor, John, Jr. (C/S-S-J); Zimmermann, Richard L. (C/S-S-J).
Kountz — Brownlee, Curtis M. (J).
Longview — Boling, Don R. (R,C/S-S-J); Crowder, William T., Jr. (M).
Lubbock — Etz, George, Jr. (C/S-S-J).
McCamey — Smith, Donald R. (C/S-S-J).
Midland — Brady, Robert H. (J); Bynum, Rufe S., Jr. (M); Hoy, George R. (R,C/S-S-J); McDaniel, Gene E. (C/S-S-J).
Odessa — Clarke, Kenneth (J).
San Antonio — Bodine, Edgar E. (C/S-S-A).
Sundown — Wintle, James V., Jr. (R,C/S-S-J).
West Columbia — Olansen, Norman A. (C/S-S-J).
Yoakum — Eissler, Victor C. (R,C/S-S-J).

WYOMING

Casper — McOsker, Dick E. (R,C/S-S-J); Vitt, Alfred W. (M).
Rock Springs — Anders, Sidney D. (R,C/S-S-M).

CANADA

Alberta — Clark, James D. (M); Freeborn, William D. (J); Strople, Douglas G.

AFRICA

Tunis — Rochet, Jean P. (J).

SAUDI ARABIA

Dhahran — Schlieman, William H. (C/S-S-J

★ ★ ★

Section Delegates Officers Elected

In accordance with resolutions from the Feb. 17, 1951, meeting of the Council of Section Delegates at St. Louis, the Executive Committee of AIME drafted amendments to Articles 6 and 10 of the AIME bylaws. In September and October, these amendments were submitted to the Delegates who, by mail ballot, voted the adoption of the amendments. The amended Articles are:

Article 6 — There shall be one regular annual meeting of the Council at the time of the annual winter meeting of the Institute. This meeting shall precede, by a day or so, the scheduled Board meeting.

Additional special meetings may be authorized by the Executive Committee of the Council.

Article 10 — The current Executive Committee of the Council shall constitute the Nominating Committee for officers and members of the Executive Committee for the following year.

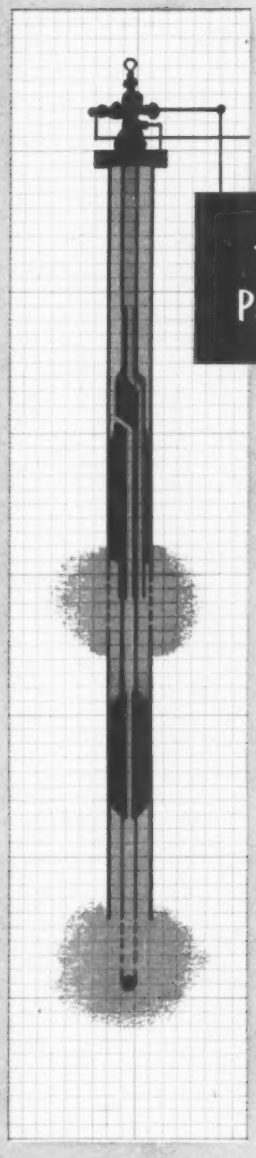
In selecting the nominees, the Committee shall consider the principal professional interests as well as the geographic location of the nominees and shall keep in mind the necessity for rotating the nominees for chairman, vice-chairman and secretary through the three branches of the Institute.

The report of the Nominating Committee shall be submitted at the annual meeting of the Council, at which time additional nominations will be received from the Council at large. The election of officers will be by written ballot either at the Council meeting or by letter ballot at some time before Nov. 1. The elected officers and members of the Executive Committee shall assume office on Nov. 15 for a one-year term.

Following the approval of these amendments, the Executive Committee acted as the Nominating Committee and submitted a slate of Council officers for 1952 to the Delegates. By letter ballot, the Delegates elected the following officers of the Council for 1952: Chairman, Jack A. Crichton (North Texas); Vice-Chairman, Allan T. Cole (Florida); and Secretary, Merton I. Signer (Colorado). The Executive Committee nominations included W. C. Leonard (North Pacific), W. K. Bock (Cleveland), W. W. Leonard (East Texas) and C. Evans, Jr. (Pennsylvania Anthracite). ★ ★ ★

— It's a Fact —

Sales taxes accounted for 16 per cent of the total federal revenue in 1950.



Pay Off, or Pay-out?

A small producer recompleted as a dual well very often turns a break-even operation into a pay-out. The installation of an Otis "Selective" Cross-Over Nipple Assembly is especially recommended in such operations where there is little margin for costly workover jobs to maintain maximum production. For example, the Otis nipple assembly allows flow courses to be changed by wire line operations *under pressure, at the surface* — without the expense and downtime required to kill the well and round-trip the tubing — by simply running in an Otis Type X (cross-over) removable wire line choke (diagram) or a Type R (parallel) choke. Both chokes pack off gas-tight in the nipple, and at no time do the fluids commingle. The Otis cross-over head is made up as permanent sub-surface equipment on an Otis Type C or D "Selective" Cross-Over Packer or certain other production packers. A Baker-Otis "selective" dual-zone production hook-up, for instance, consists of an Otis cross-over nipple and a Baker Model D retainer production packer. If you contemplate a dual completion or recompletion, ask your nearest Otis office to explain more fully these and many other operating advantages — features that are not available in any other cross-over equipment on the market. Otis Pressure Control, Inc., 6612 Denton Dr., P. O. Box 7206, TWX DL-220, Dallas; offices in Houston, Corpus Christi, Victoria, Longview, Falfurrias, New Iberia, Houma, Shreveport, Odessa, Oklahoma City, Elk City.

PRESSURE CONTROL OTIS SERVICE - EQUIPMENT

Cross-Over Nipple Assembly

Institute Shows $8,000 Surplus for 1951

Membership at the end of the year 1951 was 19,711 including 2,228 Student Associates. The data in the third column include these Student Associates.

Amounts shown in the fourth column are included in the Institute totals of column one.

1. This includes all the cash dues income received from new and old members of all grades.
2. All cash initiation fees received.
3. Net income received from advertising in the three journals. The figure was $72,273 for *Mining Engineering*; $39,844 for the *Journal of Metals*; and $31,564 for the *Journal of Petroleum Technology*. Income in 1950 was $54,572, $30,390, and $18,443 from these sources, respectively.
4. Receipts from individual sales, nonmember subscriptions, and multiple subscriptions of members.
5. Includes Transactions volumes and the Petroleum Statistics volume.
6. Sales of all other printed matter except special volumes sponsored by certain Funds. Includes a considerable sale of preprints and reprints of Technical Papers.
7. Does not include dividends and interest from certain Funds whose income reverts to those Funds.
8. Miscellaneous income not included in any of the above categories.
9. The total income compares with $493,197 in 1950, an increase of $29,000.
10. Consists principally of appropriations made to Local Sections (about $10,000), traveling expenses of delegates to the Annual Meeting, and $866 refunded to Local Sections as representing 10 per cent of the initiation fees paid by members in their respective Local Section territories.
11. Includes all appropriations made to Divisions and Branches and salaries and expenses of paid Division and Branch officers; also rental for offices used for Divisional and Branch purposes.
12. All expenses of the AIME Secretary in New York and in the field.
13. Net cost of Annual and Mid-Year meetings and such other meeting expense as not properly chargeable to Branches, Divisions, or Local Sections or borne by them. Profits or losses on social functions at all-Institute meetings are for the account of the host Local Section.
14. Net AIME contribution to the support of the Engineering Societies Library. A further contribution to the Library comes from interest on the James Douglas Library Fund of $106,000.
15. AIME headquarters occupies 7,157 sq ft in the Engineering Societies Building in New York and contributes about $2.40 per ft per year for building maintenance. A small part of this is charged in item 11 for Mining and Metals Branch office space; the rest appears here.
16. Includes the salaries and expenses of the editorial and advertising staffs; paper, printing, and distribution. Net cost can be obtained by subtracting items 3 from 4 from this total.
17. Printing, paper, binding, and distribution of Transactions and Petroleum Statistics volumes.
18. Compiling, printing, and distributing the 40-page directory of officers, committee personnel, Local Sections, Student Chapters, etc., distributed with the journals last spring.
19. Cost of reprints and other miscellaneous publications not otherwise mentioned or paid for by specific Funds.
20. Salaries and expenses of members of the New York staff not primarily concerned with publications, accounting, or membership; telephone, telegraph, general postage, stationery, and other supplies.
21. Salaries and all expenses in the Accounting Department at New York.
22. Salaries and all expenses connected with approaching prospects for membership, processing applications, and recording changes of address and title.
23. Cost of noncontributory insurance and annuity policies for AIME employes of more than five years' service. Income from canceled policies redounds to the Pension Fund so this item may vary greatly from year to year.
24. Various types of insurance carried by the Institute.
25. Maintenance of furniture and equipment.
26. Larger than usual because of purchase of new equipment and scrapping old; disposal of unsalable volumes; and adjustments for past years.
27. Reserve set up for probable loss on delinquent accounts.
28. Expense that does not fit into any of the above classifications.
29. Compares with expense of $508,051 in 1950, an increase of $6,016.

It should be noted that the Member and Associate Member paying $20 dues is subsidizing completely the Senior Members (members of at least 30 years' standing and over 70 years old who apply for this grade) and Honorary Members, neither of whom pay any dues but who receive all privileges. They also subsidize in part Junior Members, most of whom pay $12; and to a large extent they subsidize Student Associates, who pay $4.50.

INCOME AND EXPENSE OF THE AIME IN 1951

INCOME	Total Amount	Per Cent of Income	Amount Per Member	Petroleum Branch Total
1. Dues	$295,348	56.5	$14.98	$ 69,425.48
2. Initiation	11,054	2.1	0.56	2,296.14
3. Advertising	143,681	27.5	7.29	31,563.99
4. Sales journals	22,982	4.4	1.16	4,307.27
5. Sales annual volumes	22,142	4.2	1.12	8,853.56
6. Sales other publications	15,864	3.0	0.80	4,119.25
7. Dividends and interest	4,203	0.8	0.21	1,008.93
8. Miscellaneous	6,802	1.3	0.35	5,432.63
9. Totals	**$522,076**	**99.8**	**$26.47**	**$127,007.25**
EXPENSES		**Per Cent of Expense**		
10. Local Sections	$ 14,280	2.8	$ 0.72	$ 3,452.26
11. Divisions and Branches	54,011	10.5	2.74	17,753.73
12. Secretary's expense	2,116	0.4	0.11	508.42
13. Meetings	4,188	0.8	0.21	(20.36)
14. Library	6,522	1.3	0.33	1,565.26
15. Building rental	13,035	2.5	0.66	3,128.49
16. Journals	248,566	48.4	12.58	49,340.77
17. Annual volumes	36,195	7.0	1.83	5,769.78
18. Directory	2,194	0.4	0.11	566.66
19. Other publications	7,561	1.5	0.38	14,784.59*
20. General and administrative	46,574	9.1	2.36	10,721.61
21. Accounting	25,568	5.0	1.29	6,120.48
22. Membership	22,945	4.5	1.16	5,546.93
23. Pension	4,387	0.9	0.22	1,052.87
24. Insurance	505	0.1	0.03	121.29
25. Furniture and fixtures	1,454	0.3	0.07	349.02
26. Depreciation of equipment	12,500	2.4	0.63	3,000.00
27. Delinquent accounts	3,000	0.6	0.15	720.00
28. Miscellaneous	8,966	1.7	0.45	2,518.34
29. Totals	**$514,067**	**100.2**	**$26.03**	**$127,000.14**

*Includes expense of publishing Statistics Vol. 5 ($12,620.76) and reprints ($2,163.83).

Board of Directors Discusses Future Dues

An important item on the agenda for the Board of Directors' meeting on Feb. 17 was that of the policy on future dues. Until 1950, AIME dues were $15 for Members and Associate Members and $10 for Junior Members for the first six years of such membership, thereafter $15. As recommended by the Section Delegates at their meeting in San Francisco in 1949, and as subsequently confirmed by a vote of 78 per cent of the voting membership, these dues were raised by $5 for Members and Associate Members and by $2 for Junior Members for the years 1950, '51 and '52 only. In 1953 the dues go back to the former level unless the Directors and the membership, through a referendum, vote otherwise.

The deficit for 1949 was $72,048. With the higher dues schedule, the deficit in 1950 dropped to $14,854. This last year, 1951, in spite of increased costs, a surplus of $8,009 was achieved. Two principal factors in the improvement were increased advertising income from the journals, and the fact that no Directory was published in 1951. The preliminary budget for 1952 shows a surplus of $6,000.

In studying the probabilities for 1953, several factors must be considered. Enrollment of new members should result in an increase in the dues income, and advertising income will also likely increase, as it has done each year since 1949 when the new journals were established. On the other hand, if the value of the dollar continues to decline, unit costs of what the Institute buys will increase. (Based on 100 cents for the 1935-39 dollar, the dollar at the end of 1949 was worth 60 cents; 1950, 56 cents; and 1951, 53 cents.) Further, during the ten years of deficits the Institute's reserve funds were tapped by an amount exceeding $200,000, bringing those available to meet such deficits virtually to the vanishing point. Prudence would indicate that some restitution should be made to these reserve Funds to take care of possible future requirements. Such restitutions must be made from surpluses over the next few years.

Data were presented at the Board meeting indicating that, based on billings for 1952 dues, income from dues payments would be reduced by approximately $69,000 if the dues went back to the pre-1950 level. This would undoubtedly force a radical cut in the services performed, and a reduction in the quantity of published material, with a quite possible resultant reduction in advertising income as well. There was considerable discussion of a proposal from the Petroleum Branch that separate dues be established for each Branch, consistent with providing sufficient income to meet Branch expenses, and allowing a sufficient surplus to pay back the amount taken from reserve funds over a ten-year period. The final vote, with but two or three Directors dissenting, was that an amendment to the bylaws continuing the present dues schedules for all classes of membership be submitted to the membership for a referendum. A statement will be included with the ballot, and published in the JOURNAL OF PETROLEUM TECHNOLOGY. ★ ★ ★

USC Student Chapter To Hold Spring Meeting

The University of Southern California Student Chapter of AIME will conduct its third annual Spring Meeting May 23 in Founders Hall. A banquet will be held the same evening in the Commons Building of the Los Angeles university.

The morning session of the meeting will be devoted to papers by students in the petroleum engineering and geology departments of USC. The afternoon sessions will be given over to talks by industry men. Speakers will include Sam Yuster, professor of petroleum engineering at UCLA; Milton Loy, Schlumberger Well Surveying Corp.; Jerry Thomas, Signal Oil and Gas Co.; and Frank Miller, U. S. Bureau of Mines and the University of California at Berkely.

The morning student papers will be judged and prizes will be awarded to the winning students at the evening banquet. Paul Andrews, Signal Oil and Gas Co., is chairman of the judging committee and will present the prizes. ★ ★ ★

Haider Tour

Continued from Page 25, Section 1

Meeting in New York in February.

Joe B. Alford also spoke at the various meetings on Petroleum Branch affairs. To the student chapters, he outlined the history of petroleum engineering and the development of the profession's professional society, the AIME.

President Haider will attempt to visit other local sections throughout the year as time permits. ★ ★ ★

Petroleum Fellowships Offered by Stanolind

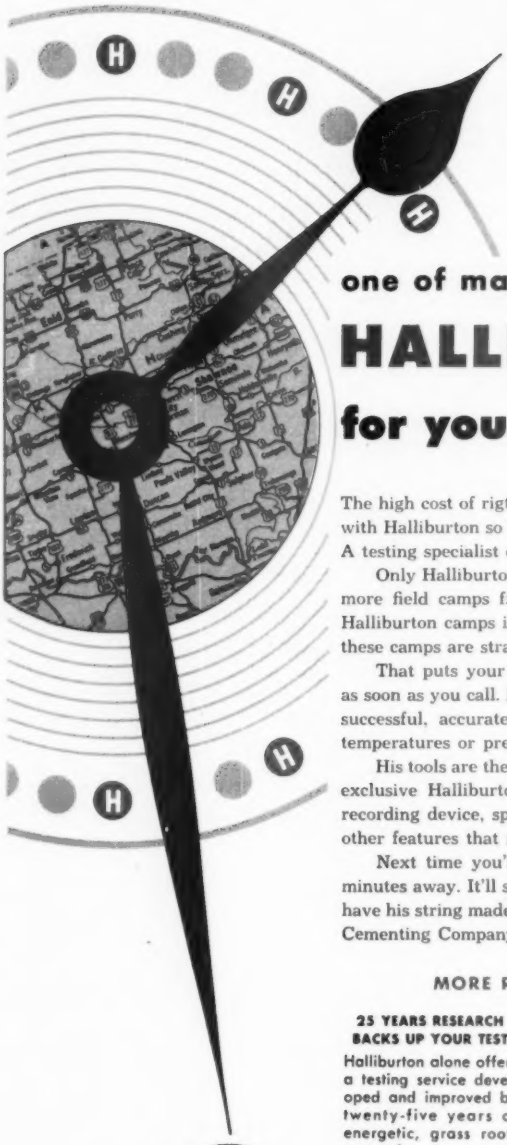
Stanolind Oil and Gas Co. has announced the establishment of 14 fellowships for advanced study and research in various fields of petroleum science at 12 colleges and universities for the school year 1952-1953. Each of the fellowships is valued at $1,250, plus tuition and laboratory fees, and will be in force for one academic year.

The schools and fields of study selected by the oil company are: Columbia University, New York City, geophysics; University of Kansas, mechanical engineering; Louisiana State University, chemistry and geology; University of Michigan, chemical engineering; University of Oklahoma, petroleum engineering; University of Pennsylvania, accounting; Pennsylvania State College, petroleum engineering; St. Louis University, geophysics; University of Texas, geology and petroleum engineering; Texas Agricultural and Mechanical College, petroleum engineering; University of Tulsa, petroleum engineering; and Yale University, geology.

The fellowships are available to all qualified graduate students upon application to the respective universities. Throughout the tenure of the fellowships, company representatives from the various departments interested in the work will maintain contact with the fellows in order to discuss practical as well as theoretical aspects of the problems. ★ ★ ★

Junior Members Aided By Reinstatement Policy

Hereafter, Student Associates and Junior Members who have been dropped from the AIME rolls because of arrears in dues will have such arrears canceled if they are obligated to pay an initiation fee. If such persons have passed their 30th birthday they must be reinstated as Associate Members or Members and are thus liable for the $20 initiation fee, though it may be paid in $5 annual instalments. The Board, which took the above action at its meeting on Feb. 17, felt that a charge for arrears in dues in addition to the initiation fee and current dues was too much of a hardship. Reinstatement of other members who had heretofore paid an initiation fee is made without any charge except for current dues unless they were in arrears for dues when their membership terminated, in which case the arrears must be paid, but not in excess of $20. ★ ★ ★



JUST MINUTES AWAY!

one of many reasons why

HALLIBURTON'S *best* for your DRILL STEM TEST!

The high cost of rigtime makes waiting expensive—but you needn't wait long with Halliburton so handy. When you're ready for your test, so's Halliburton. A testing specialist can be there in a matter of minutes.

Only Halliburton can offer such speedy service, for Halliburton has many more field camps from which to serve you. At last count there were 1770 Halliburton camps in the oil producing areas of the U.S. and Canada. 139 of these camps are strategically located in the Mid-Continent.

That puts your Halliburton Tester only minutes away and ready to go as soon as you call. He comes fully prepared and equipped to give you a safe, successful, accurate test—no matter how deep your well, how high the temperatures or pressures.

His tools are the most advanced and specialized in the industry, with many exclusive Halliburton features. These include the Bourdon Tube pressure recording device, special-duty packers, curved J-slots, automatic locks, and other features that make misruns a rarity with Halliburton.

Next time you're ready for a test, remember that Halliburton is only minutes away. It'll save you rigtime. Phone your Halliburton Tester and he'll have his string made up before you come out of the hole. Halliburton Oil Well Cementing Company, Duncan, Oklahoma.

MORE REASONS WHY HALLIBURTON'S BEST:

25 YEARS RESEARCH BACKS UP YOUR TEST

Halliburton alone offers a testing service developed and improved by twenty-five years of energetic, grass roots research.

MOST ADVANCED TOOLS AND TECHNOLOGY

Halliburton's highly specialized tools and exclusive features, its superior knowledge and experience, help make misruns a rarity.

GREATER ACCURACY IN PRESSURE RECORDING

The Bourdon Tube Pressure Recording Device, exclusive with Halliburton, gives you far greater accuracy at no extra cost.

HALLIBURTON

YEARS AHEAD IN DRILL STEM TESTING

AIME Directors Vote On Bylaws Amendments

Several proposals for amendment of the AIME bylaws were approved by the Board of Directors at its meeting on Feb. 17, and were to be voted on at the April 16 meeting of the Board. Two proposed changes regarding handling of AIME funds were announced in the March issue of the JOURNAL OF PETROLEUM TECHNOLOGY. An explanation of the remaining amendments follows.

A proposal emanating from the Council of Section Delegates in 1951, that dues of new members be prorated according to the number of months remaining in the calendar year following the date of election, was favorably regarded by the Directors at their Feb. 17 meeting. They recommended a change in the bylaws to make this effective. It is therefore proposed to change Art. II, Sec. 2, 3d sentence as follows:

Present wording: "Members, Junior Members, or Associate Members elected on or after June first of any year shall pay, on receipt of Treasurer's statement, one-half of said amount for the year of election, and if elected in the month of October, November, or December, the candidate may defer acceptance to the first of the following year without loss of status."

To be revised to read: "*Newly elected Members, Associate Members, or Junior Members shall, on receipt of Treasurer's statement, pay the current year's dues on a pro rata basis for the number of months remaining in the calendar year following the month of election.*"

A proposal originating last year with the Mining and Metals Branch Councils, that Branch Council Chairmen be ex-officio members of the AIME Board of Directors, was regarded favorably by the Board at its meeting on Feb. 17. This had been advocated also by a special Committee on Increased Divisional Representation on the Board, of which John R. Suman was chairman. This committee had also recommended three-year terms for Divisional representatives, instead of the present one-year term for Divisional Chairmen, but the Board took no action on this part of the Committee's recommendation.

The proposed changes would add the words in italics to Art. VI, Sec. 1:

"The number of Directors of this Corporation is 27, consisting of one President, one President-elect, one Past President, six Vice-Presidents, and 18 other Directors, to be elected as hereinafter provided; and in addition the Chairman of each duly constituted professional Division *and of each Branch Council* of the Institute, ex officio, shall serve as a Director, with full voting power, during his term as Chairman, *provided, however, that such ex-officio Directors shall have but one vote if they are already duly elected members of the Board.*

"At the regular November meeting of the Board of Directors or Executive Committee, the chairman thereof shall declare to be elected, as provided in Art. IX of these Bylaws, nine Directors, of whom one shall also be designated as President-elect, and of whom two shall be designated as Vice-President. The nine Directors, including the Directors designated as officers, together with the newly elected Division *and Branch Council* Chairmen in their capacity as ex-officio Directors, shall take office at the annual business meeting of the Institute next following the meeting at which they were declared elected . . . "

Necrology

William B. Rose (Member 1930) died on Nov. 19, 1951. Rose was born at Uhrichsville, Ohio, on Feb. 6, 1892. He attended Wooster College, Wooster, Ohio, and MIT, Cambridge. After graduation he was a chemical engineer for Ludlow Mfg. Associates, Ludlow, Mass. He served with the Army Engineers, and following his discharge joined the Welch Dry Kiln Engineering Co., New Orleans, as a consulting engineer. In 1919 he was a research associate at MIT and in 1924 joined the Vacuum Oil Co. He remained with this firm until 1935. He then was employed by the Pure Oil Co., research and development laboratories, Chicago.

Ernest Arthur Satchell (Member 1927) died recently in Surrey, England. Born in London on Nov. 12, 1888, he graduated from Alleyn's College at Dulwich, London. He was employed by the Stanolind Oil Co. as a roustabout. In 1911 he joined the Nevada Petroleum Co. as chief clerk. He was with the British Army during the first world war and then went to Mexico for the Pan American Petroleum and Transport Co., becoming production superintendent for this firm in 1921. In 1926 he joined the Lago Petroleum Corp., Venezuela, as general superintendent and in 1930 returned to England. Later he joined the Iraq Petroleum Co., Ltd.

Raleigh P. Trimble (Member 1919) died in January, 1952. Trimble attended the University of Oregon (1898-1900); University of Michigan (1900-01); and University of Washington (1915). In 1907 he was general manager for the Keating Mining Co., Wardner, Idaho. For two years he held the same position with the Roche de Boul mine at Hazelton, B. C., and in 1911 joined the Juniper Creek Mines Co. He became president of the Gore Exploration Co. in San Francisco, and in 1922 moved to Los Angeles for the Rio Bravo Oil Co.

Donald K. Weaver (Member 1940) died recently. Born in 1897 at La Porte, Ind., he attended Stanford University. He graduated in 1922 with the AB degree in geology. After graduation he was employed as exploration geologist for the Standard Oil Co. of California in Montana, Texas, Venezuela and California. For six years Weaver was employed by The Texas Co., Los Angeles, and in 1932 joined the Wilshire Oil Co., Inc., as field manager.

Norman L. Dorn, vice-president of Lane-Wells Co., died at his home in Long Beach, Calif., March 2, 1952. A native of Cleveland, Ohio, Dorn spent most of his life in Nevada and California. Before joining Lane-Wells in 1937, he was with Shell Oil Co. for 18 years in a progression of positions leading to his capacity of superintendent of production in the Southern Division at Long Beach. He directed engineering activities of Lane-Wells from 1937 until February of this year, when he became vice-president and consultant. ★ ★ ★

To ease the transition from Student Associate to Junior Member, the Board proposed that the bylaws be changed to reduce to one the number of endorsers needed by graduating students in applying for the higher status. The Student Associate would be sent an application blank immediately on leaving school. This would be endorsed by one member, but not the same member that originally endorsed him for Student Associateship. The Admissions Committee would act upon this application and if their recommendation was favorable the Board would elect the applicant to Junior Membership at the end of the year, when his Student Associateship would expire. He would then be billed for the succeeding year's dues as a Junior Member. To permit this change in procedure, the Board was to vote, at its April 16 meeting, on the following change in the pertinent bylaw, Art. I, Sec. 9, first sentence:

Present wording: "Every candidate for election as a Member, Junior Member, or Associate Member must be proposed for election by at least three Members, Junior Members, or Associate Members, must be approved by the Committee on Admissions, and must be elected by the Board of Directors, and not less than three-fourths of the votes cast shall be necessary to election."

To be revised to read: "*Every candidate for election as a Member, Junior Member, or Associate Member must be proposed for election by at least three Members, Junior Members, or Associate Members, provided, however, that in the case of a Student Associate applying for Junior Membership only one proposer in addition to the member who nominated him for Student Associateship be required. All candidates for election to membership must be approved by the Committee on Admissions*" . . . *etc., as above.* ★ ★ ★

Harry H. Power Named MIED Chairman

Harry H. Power, University of Texas petroleum engineering professor, is the new chairman of the AIME Mineral Industries Education Division.

During 1952-53, the Division will seek ways to fill the unprecedented demand for mineral industries engineers and to push research toward better utilization of the nation's mineral supplies. The Division's work covers training and research in petroleum, mining, geological, ceramic, geophysical and metallurgical engineering. ★ ★ ★

Book Reviews

Energy Sources — The Wealth of the World

By Eugene Ayres and Charles A. Scarlott. McGraw-Hill Book Co., New York, Toronto, London, 1952. 344 pp., illus., diagrs., charts, tables, 9¼ x 6¼ in., cloth, $5.00.

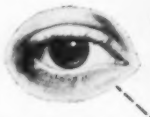
A thorough survey of the world's energy sources, including oil, coal, hydro-electricity, solar and nuclear energy, wind and tide powers and others, this book presents in readable form both the historical aspect and an analysis of our prospects for the future. Size of resources, technology of production, efficiency of conversion, reasons for waste and progress in conservation are covered. The book is an expansion, with new statistical and interpretative data added, of the paper, "Major Sources of Energy," presented at the API meeting in Chicago, Nov. 9, 1948.

Principles of Petroleum Geology

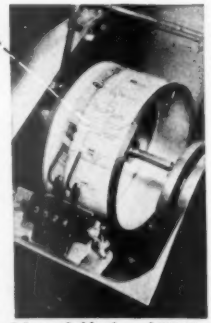
By W. L. Russell, McGraw-Hill Book Co., New York, Toronto, London, 1951. 508 pp., diagrs., charts, maps, tables, 9¼ x 6 in., cloth, $7.00.

An advanced textbook and reference volume which discusses the principles, methods and techniques which are of importance in petroleum geology. Subjects treated include the following: origin and accumulation of oil; important structures; classification of fields; geophysics; stratigraphic features such as reefs; and the various well-logging methods, including gamma ray and neutron well logs. Practical applications are emphasized, and illustrative examples supplement the text.

SEE formation changes *as you drill* WITH GEOLOGRAPH



With Geograph, you actually watch the drilling change as the bit bites into contrasting strata — foot by foot! You'll find that this subsurface control, while drilling, results in a higher percentage of successful drill stem tests; fewer and more correctly placed cores; accurate determination of net pay thickness and elimination of many depth corrections!



Abilene, Houston, Odessa, Lubbock and Wichita Falls, Texas - Bakersfield, Calif. - Shreveport and Baton Rouge, La. - Casper, Wyo. - Oklahoma City, Okla.

"TIME WILL TELL"

THE GEOLOGRAPH CO. INC.

P. O. Box 1281 Oklahoma City 1, Okla.

Advertisers' Index

	Page
A-1 Bit & Tool Co. — *Calvin L. Clausel, Jr., Houston*	Sec. 1—2
Axelson Manufacturing Co. — *Heintz & Co., Los Angeles, Calif.*	*
Baash-Ross Tool Co. — *Dozier-Eastman & Co., Los Angeles, Calif.*	Sec. 1—29
Baroid Sales Division — *Darwin H. Clark Co., Los Angeles*	*
Baker Oil Tools, Inc. — *Theo. M. Martin Co., San Gabriel, Calif.*	*
Barret, William M., Inc. — *Bozell & Jacobs, Shreveport, La.*	*
Black, Sivalls & Bryson, Inc. — *R. J. Potts-Calkins & Holden Adv., Kansas City, Mo.*	*
B and W Incorporated — *Lester C. Nielson Co., Huntington Park, Calif.*	Sec. 1—5
Clark Bros. Co., Inc. — *Harold Warner Co., Buffalo, N. Y.*	Sec. 1—6, 7
Cooper-Bessemer Corp. — *Griswold-Eshleman Co., Cleveland, Ohio*	Sec. 1—9
Core Laboratories, Inc. — *Duvall Williams, Dallas, Tex.*	*
Dale Company — *Lester C. Nielson Co., Huntington Park, Calif.*	*
Dowell Incorporated — *MacManus, John & Adams, Inc., Detroit, Mich.*	Sec. 1—10
Eastman Oil Well Survey Co. — *Ted Workman Advertising, Dallas, Tex.*	Sec. 2—3
Geograph Co., Inc. — *Lowe Runkle Co., Oklahoma City, Okla.*	Sec. 2—10
Halliburton Oil Well Cementing Co. — *Hill & Christopher, Los Angeles, Calif. Bachrodt, Newell, O'Kane and Gano, Chicago, Ill.*	Sec. 1—1, 22, Sec. 2—8
Infilco, Inc. — *Ruthrauff & Ryan, Hollywood, Calif.*	Sec. 1—17, 18
Johnston Testers — *Wallace Davis & Co., Houston, Tex.*	*
Keystone Development Corp. — *Brennan Advertising Agency, Houston, Tex.*	*
Lane-Wells Co. — *Darwin H. Clark Co., Los Angeles, Calif.*	Sec. 1—30
Larkin and Co. — *Peter Baycura Adv., Butler, Penn.*	*
Lufkin Foundry & Machine Co. — *Cudlipp Advertising Agency, Lufkin, Tex.*	Sec. 1—8
Magnet Cove Barium Corp. — *Rives, Dyke and Co., Houston, Texas*	Third Cover
McCullough Tool Co. — *R. P. Costerline Advertising, Los Angeles, Calif.*	*
Lee C. Moore Corp. — *Watts, Payne Advertising, Tulsa, Okla.*	Sec. 1—4
Oil Base, Inc. — *Dozier-Eastman & Co., Los Angeles, Calif.*	*
Otis Pressure Control, Inc. — *Don Goodrich, Dallas, Tex.*	Sec. 2—5
Pelton Water Wheel Co. — *Edward A. Stratman Adv., Huntington Park, Calif.*	*
Professional Services	Sec. 1—26
Schlumberger Well Surveying Corp. — *Rives, Dyke & Co., Houston, Tex.*	Second Cover
The Second National Bank, Houston, Tex. — *Gano, Bachrodt, Edwards, Inc., Houston, Tex.*	*
Sperry-Sun Well Surveying Co. — *Wallace Davis & Co., Houston*	*
Sinclair Research Laboratories, Inc. — *Kenyon & Eckhardt, Inc., Adv., New York*	*
United Geophysical Co., Inc. — *Dozier-Eastman & Co., Los Angeles, Calif.*	Fourth Cover
Well Surveys, Inc. — *Watts, Payne Advertising, Tulsa, Okla.*	*
Zublin Flexible Drill Pipe — *Roy F. Irvin Advertising, Los Angeles, Calif.*	*

* In previous issues

MAGCOBAR

ONE OF THE BEST THINGS THAT EVER HAPPENED TO THE OIL INDUSTRY

More than 350 Magcobar Dealers from Canada to the Gulf Coast are ready to serve you Night or Day.

When Magcobar entered the field just a little more than 10 years ago, mud weighting materials with a specific gravity of 4.0 (approximately 84% barium sulphate) were accepted as standard for use. Drilling muds weighing over 15 pounds per gallon with low viscosity seemed next to impossible.

Today, the standard for mud weighting materials is a specific gravity of 4.25 to 4.35 (approximately 95% barium sulphate). Drilling muds weighing up to 19 pounds per gallon with low viscosity are used in many heavy pressure areas.

Yes, drilling mud quality is much higher today because Magcobar developed and pioneered the first commercial production of barite beneficiated by the flotation process in 1940. This method produced barite that was not only higher quality, but also very uniform. Furthermore, by this process, low grade barite ores could be turned into high grade products . . . and this alone added many millions of tons of reserves which were made available to the oil industry for drilling mud.

Since those early days, the oil industry's wide acceptance of Magcobar's high quality products, good service and fair and reasonable prices has enabled Magcobar to be of even greater service to the only industry it serves.

So when you need dependable drilling mud service, call Magcobar first. Magcobar is one of the best things that ever happened to the oil industry.

Magcobar

Complete

DRILLING MUD SERVICE

DEALER

MAGCOBAR • MAGCOGEL • HIGH YIELD • MAGCO-FIBER • XACT CLAY • FIBER SEAL • LEATHER-FLOC • FORM-A-PLUG • CELL-O-SEAL SALT GEL • MAGCO-PHOS • RED OX • MAGCO-MICA • TANNATHIN JEL-OIL MUD • JEL-OIL "E" • "E" CONCENTRATE • NOHEEVE MY-LO-JEL PRESERVATIVE • QUEBRACHO • CHEMICALS

First IN BRAZIL

In May, 1940, UNITED started the seismic survey of BRAZIL'S 3½ million square miles of land. From that date on, UNITED has been busy determining the oil possibilities of this vast country.

UNITED GEOPHYSICAL

UNITED

GEOPHYSICAL COMPANY

Herbert Hoover, Jr. President

1300 S. MARENGO AVENUE, PASADENA 5, CALIFORNIA

ABARTADO 1085, CARACAS, VENEZUELA